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FRESHWATER FISH PROCESSING AND EQUIPMENT IN SMALL PLANTS

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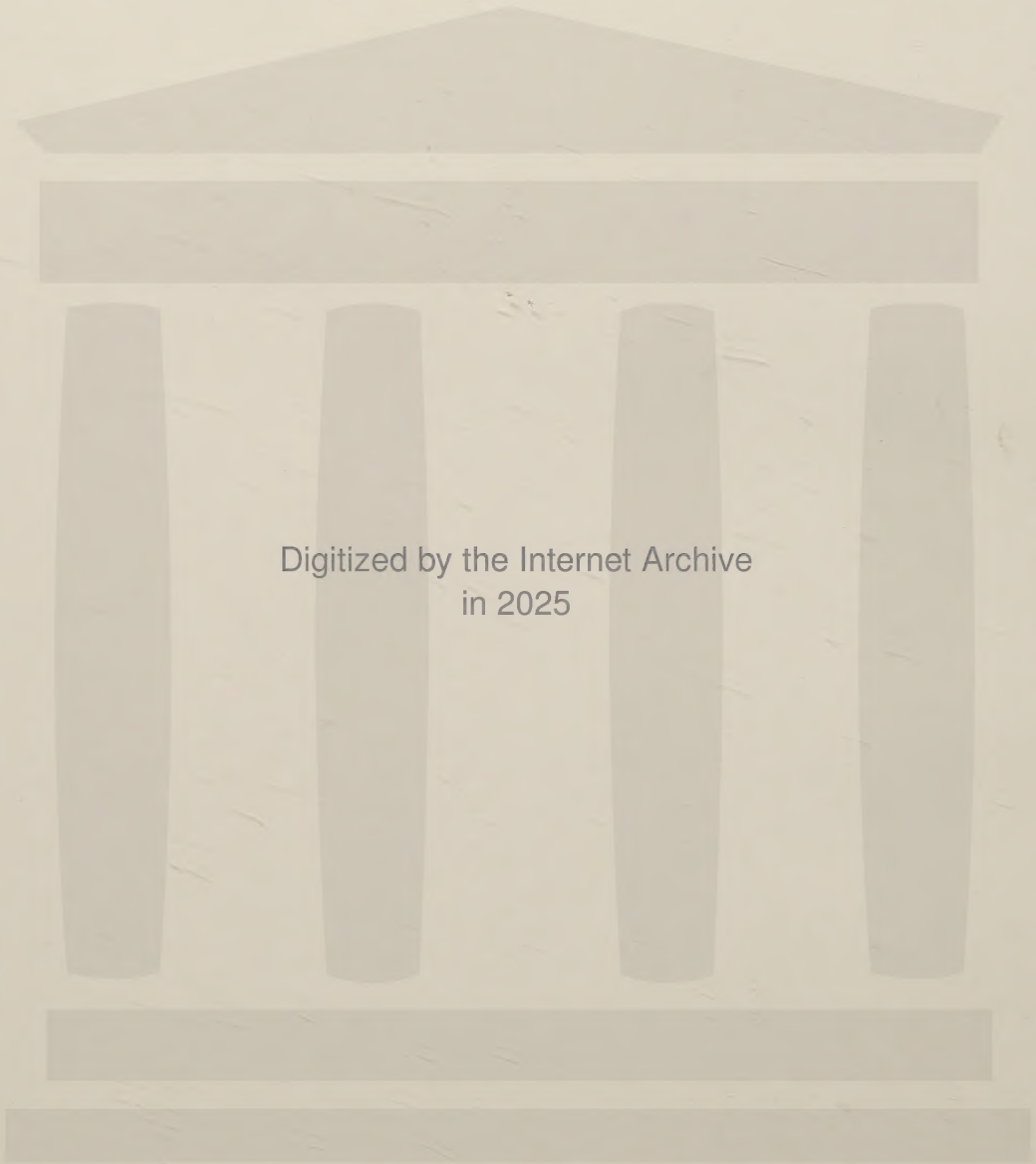

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FRESHWATER FISH PROCESSING AND EQUIPMENT IN SMALL PLANTS

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, February 1996

PREPARATION OF THIS DOCUMENT

The Eighteenth Session of the FAO European Inland Fisheries Commission (EIFAC) held in Rome from 17 to 25 May 1994, noted with satisfaction that high quality freshwater fish products are becoming increasingly popular, especially in the more affluent countries. It recommended technologies with emphasis on cyprinids, and the provision of support for further research into new technologies for high quality fish products.

This study was undertaken following the recommendations of the above session and is based on the situation of the freshwater fish processing sector in Poland.

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ABSTRACT

This document provides a brief review of the inland fisheries situation in Europe followed by the consideration of freshwater fish as raw material for processing. The document also reviews the equipment used in freshwater fish processing, taking into account the different processing methods such as chilling, preserving, smoking and fish silage production. Information on different forms of packaging and labelling requirements is also provided. Finally, the requirements for fish processing plants, hygiene and sanitary regulations, location of premises, cleaning and disinfection, water quality, public health hazards (with particular reference to the European Union regulations) and fish quality criteria are discussed.

A reference list records the publications consulted in the preparation of this study and indicates further reading.

The FAO Fisheries Circular is a vehicle for the distribution of short or ephemeral notes, lists, etc., including provisional versions of documents to be issued later in other series.

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1. INTRODUCTION

According to data published by FAO, 15% of the world supply of animal proteins is derived from fish. The demand for fish as food is systematically increasing but at the same time marine resources are close to the limits of exploitation. However, aquaculture which supplies the market with both marine and freshwater fish, is fast developing. Figure 1.1 shows the most important freshwater species in Europe.

Much of the freshwater fish found on Western European markets comes from aquaculture and only very limited quantities of fish are derived from the freshwater fishery; this is due to the poor economics associated with this sector. But it should be stressed that in the Central European countries e.g., in Poland, approximately only 50% of freshwater fish come from aquaculture.

The European market is dominated by the following fish species (Table 1.1):

- rainbow trout (*Oncorhynchus mykiss*),
- European eel (*Anguilla anguilla*),
- carp (*Cyprinus carpio*).

Table 1.1 Freshwater fish production in Europe (excluding former USSR) in 1990, and a forecast for the year 2000 (Hough, 1993)

SPECIES	1990 [t]	2000 [t]
Trout	193 000	244 000
Carp	99 000	99 000
Eel	7 300	23 000
Others	5 800	5 000

Although trout production has doubled in countries of the European Union, to reach 190 000 t in the period 1980-90, the anticipated increase in production by 50 000 t by the year 2000 may testify to a restrained demand market. On the other hand, the increase in eel production is expected to exceed 200%.

Carp is greatly appreciated in Central European countries but only in limited regions of Western Europe.

Italy is the major European producer of eel, but Germany and the Netherlands are the biggest markets. Prices of eel depend on the size of fish (best prices are obtained for fish weighing more than 350 g). As much as 65% of the entire eel production comes from aquaculture, and fish derived from this source is considered more suitable for smoking than the wild fish due to its thinner skin and higher fat content.

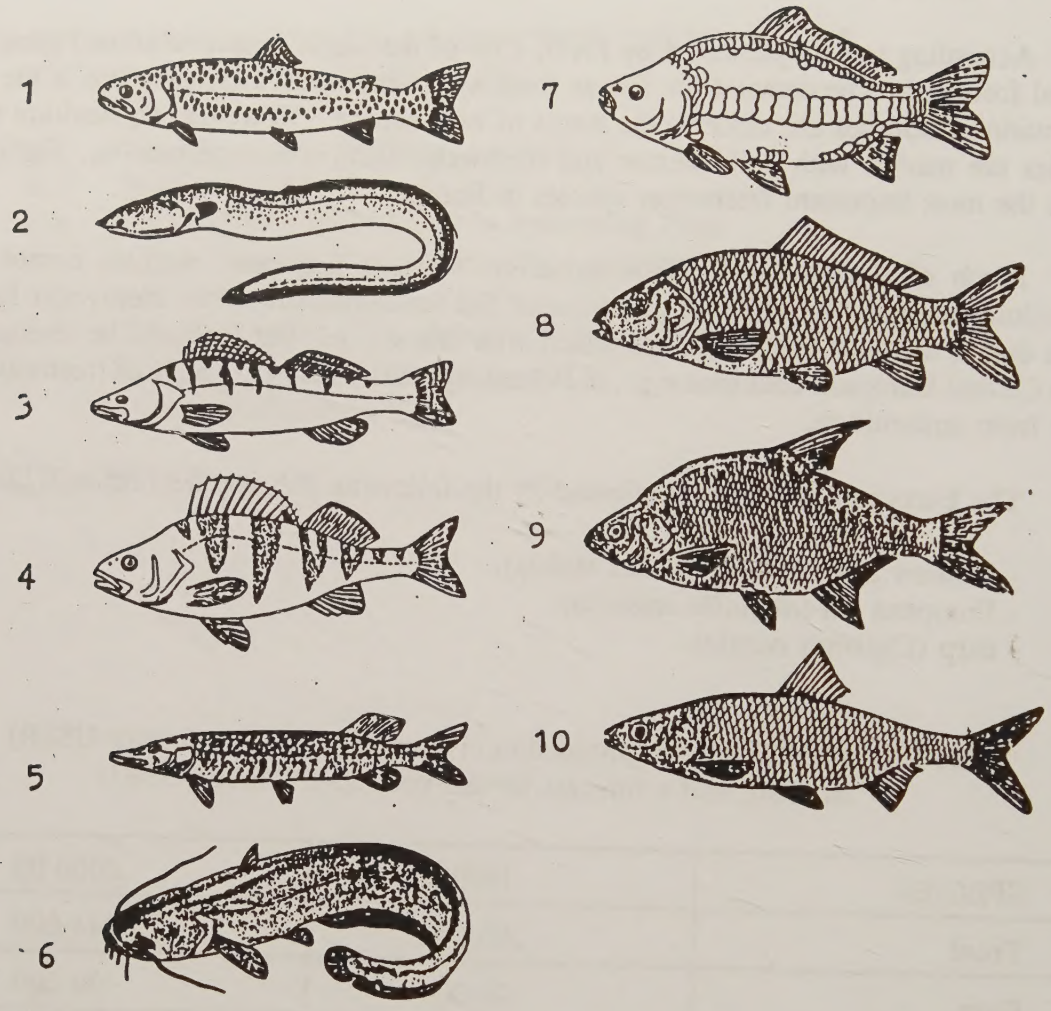


Figure 1.1 The most important species of freshwater fish:

1. Rainbow trout (*Oncorhynchus mykiss*)
2. European eel (*Anguilla anguilla*)
3. Pike-perch (*Stizostedion lucioperca*)
4. European perch (*Perca fluviatilis*)
5. Northern pike (*Esox lucius*)
6. Wels catfish (*Silurus glanis*)
7. Mirror carp (*Cyprinus carpio* var. *specularis*)
8. Scale carp (*Cyprinus carpio* var. *communis*)
9. Freshwater bream (*Abramis brama*)
10. Roach (*Rutilus rutilus*)

Until recently, freshwater fish processing was carried out mainly in kitchens at home, in restaurants and in catering centres. Occasionally, fishmonger shops and small fish processing plants produced semi-products in rudimentary conditions and placed them on the market. However, changing requirements and habits of customers in Europe created the need for an increased market supply of ready-to-cook (e.g., fillets, chunks) or ready-to-serve dishes. This trend will intensify and, if they are not to lose the market, the existing processing plants will have to be modernized. The modernization should improve economies, simplify work and, most important, improve sanitary conditions of production. The introduction of modern machines results in the growth of productivity and reduction of employment; it shortens the duration of technological processes, and makes it easier to prepare more laborious but, at the same time, more attractive products for the consumer.

However, mechanization of the processing lines is very costly, especially for small plants processing freshwater fish. In these cases, mechanization of freshwater fish processing would be limited to that equipment needed to maintain the market and meet the basic sanitary requirements imposed by the competent authorities. In addition to infrastructure and the necessary machines - for example, ice generators, washers, smoking equipment, freezers, cold stores - small processing plants could, within reason, also acquire simple, inexpensive machines which often only perform one operation.

During the Eighteenth Session of the Advisory Board of the FAO European Inland Fisheries Commission, held in Rome in 1994, it was noted with satisfaction that needs for high quality freshwater fish products are growing, especially in the more affluent countries. The Commission made important recommendations for inland fisheries, among which:

- elaboration and distribution of publications on existing technologies of fish processing and marketing, with special regard to species of the Cyprinidae family

- arrangement of aid concerning the elaboration of new technologies for producing high quality fish products.

The problems related to freshwater fish processing are not sufficiently reflected in the scientific literature. Here, an effort was made to collect the information, often based on the authors' experience or technological processes used, and on the possibilities and trends in the mechanization of freshwater fish processing, with special regard to the Cyprinidae family.

2. FRESHWATER FISH AS RAW MATERIAL FOR PROCESSING

2.1 Nutritive and Technological Values of Freshwater Fish

The manufacturing potential of the raw material as food depends on two features - the nutritive and the technological value.

2.1.1 Nutritive value

The nutritive value of dishes prepared from fish and from animal meat is comparable, but in some cases fish-based meals are advisable. In such an evaluation, many parameters, such as energetic value, quality and content of protein components, vitamins and mineral

compound content should be examined. The energetic value of eel meat is lower than that of fat beef (1 050 kJ/100 g and 1 250 kJ/100 g respectively); while in the case of trout it amounts to 600 kJ/100 g and it is lower than for lean beef, 735 kJ/100 g. Thus the meat of freshwater fish can be a valuable constituent in low-calorie diets and at the same time has a high energy content.

The composition of amino-acid proteins in fish meat is similar to that of a hen's egg. Consumption of fish together with products of plant origin which are poor in some amino-acids (lysin, threonine), enables not only a complete utilization of plant protein, but also improves the content of a diet.

The biological value of freshwater fish fats is lower than that of marine fish because the former contain fewer unsaturated aliphatic acids. Fish meat is valuable as a source of vitamins and mineral substances. It contains especially the trace metals such as: selenium, molybdenum, cobalt, whose value is emphasized by physiologists.

The definition of food stresses that the basic food ingredients as well as the raw materials used for its production must be wholesome. However, contamination of the environment is fast increasing, especially through the use of chemicals in agriculture or in industry. For that reason, certain countries or groups of countries establish limits and recommendations for permissible levels of chemical contaminants the excess of which leads to exclusion of such raw material from the production of food for human consumption. This problem, for many reasons (diets, habits, analytical methods), is far from being solved as countries have different attitudes in this respect. It may well constitute a non-tariff barrier on a free market in the future.

2.1.2 Technological value

The technological value generally depends on two parameters: the yield of preliminary processing and the quality features of fish meat and by-products. The yield of edible parts of the fish depends, first, on the species and constitution, and also on age and consequently size and maturity.

Yield is affected by the ratio between edible and inedible parts of the fish and this is a decisive factor with regard to the technological value of the fish. This ratio depends on the species. It is most favourable in the Salmonidae family, amounting to approximately 75% of the weight. For most fish species this parameter ranges from 50 to 60%. In the case of perch and most of the Cyprinidae family the yield is less than 50%. More information on the yield of preliminary processing of freshwater fish is given in Table 2.1.

Table 2.1 Average yield of preliminary processing (manual processing) of several species of freshwater fish

SPECIES	SIZE OF FISH [kg]	FORM OF PREPROCESSED FISH	YIELD [%]
Trout	> 0.35	gutted	74 - 82
Trout	> 0.35	h/g (deheaded/gutted)	62 - 74
Trout	> 0.35	fillet with skin	50 - 55
Carp	> 3.0	gutted	76 - 82
Carp	> 1 - 3.0	gutted	73 - 79
Carp	> 3.0	deheaded and gutted	55 - 61
Carp	> 3.0	chunks	49 - 57
Carp	> 3.0	fillet with skin	41 - 49
Pike-perch	> 1.0	gutted	79 - 89
Pike-perch	> 1.0	deheaded and gutted	66 - 74
Pike-perch	0.35 - 0.5	deheaded and gutted	60 - 68
Pike-perch	> 1.0	chunks	56 - 68
Pike-perch	> 1.0	fillet with skin	52 - 64
Pike	1 - 3.0	gutted	76 - 84
Bream	> 1.0	gutted	68 - 76
Bream	0.5 - 1.0	deheaded and gutted	56 - 64
Bream	0.5 - 1.0	chunks	52 - 64

Evaluation of the technological value of freshwater fish should take account of its possible utilization for different products, considering the sensory properties such as: flavour, texture, appearance, size and bone content. These parameters are decisive as to consumer's interest and thus the market demand.

Fish with high bone content are not so popular as a product for consumption. Therefore, the technological value of roach (*Rutilus rutilus*) is lower than that of pike-perch (*Stizostedion lucioperca*). The taste of freshwater fish depends mainly on the quality of their water habitat and on their food. It is known that fish (for example, carp) living in dirty and muddy ponds, have an unpleasant flavour. The flavour of wild trout from streams is better than that of fish from aquaculture. The opposite is true for eel resulting from the fact that the aquaculture eel has a more tender tissue and thinner skin.

Freshwater fish are classified according to size, larger individuals usually being preferred to small fish. This is also connected with bone content: e.g., trouts weighing about 300 g are very popular as single portions, prices increasing with popularity. The most expensive are fish weighing over 500 g which are destined for smoking. The best market value are carp of 1-2 kg, but those exceeding 3 kg have less customer appeal.

The sanitary and hygienic condition of fish and fish meat also influences the technological value. This relates to the presence of parasites and pathogenic micro-organisms.

However, the main role in evaluating technological value and usefulness is played by a set of features termed freshness. These features change during storage after the death of the fish and the intensity of the changes depends on the species, fishing conditions and storage conditions immediately after capture.

2.2 *Post mortem* Changes and Fish Quality Assurance Methods

On the death of the fish, processes of physical and chemical change caused by enzymes and micro-organisms begin to occur. The complete decay of the fish is the final result of those changes.

Post-mortem changes which take place in fish tissue occur in the following phases:

- slime secretion on the surface of fish
- *rigor mortis*
- autolysis as enzymatic decomposition of tissues
- microbiological spoilage

The duration of each phase can change or phases can overlap. This depends on storage conditions, especially the temperature which greatly influences these processes.

2.2.1 Slime secretion

Slime is formed in certain cells of fish skin and the process becomes very active just after fish death. Some of the fish, for example eel, secrete more slime than, for comparison, Salmonidae and perch. Fish which secrete great quantities of slime have poorly developed scales; very often the quantity of slime reaches 2-3% of the fish mass and that in turn creates problems during processing. The secretion process stops with the onset of *rigor mortis*.

Slime contains large amounts of nitrogenous compounds and these provide good nourishment for micro-organisms originating from the environment. Therefore, the slime spoils quickly: first giving an unpleasant smell to the fish, and second opening the way for further and deeper bacterial penetration into the fish.

2.2.2 *Rigor mortis*

Rigor mortis is a result of complicated biochemical reactions which cause muscle fibres to shorten and tighten, and finally the fish becomes stiff. *Rigor mortis* has many technological consequences. If, for example, the bones were removed prior to *rigor mortis* the length of the fillet shortens by 30%. At the same time, the fillet becomes wider and thicker because its volume does not change.

This tightness very often causes the connective tissue of individual myomeres to break; this process is termed "gaping" and results in muscle separation which is considered a quality defect. "Gaping" depends on temperature; the higher the temperature of fish at the beginning of the rigor mortis process the greater the gaping of the muscle. Therefore, during rigor mortis fish temperature should be as low as possible. For example, for roach and perch kept at 0°C *rigor mortis* begins 24 hours after death and lasts for 72-80 hours. When the same species is kept at 35°C it begins 20-30 minutes after death and stops after about 3 hours. The time rigor mortis begins and its duration depend on the fish species (e.g., for carp at 0°C it starts after 48 hours, for roach and perch at 0°C after 24 hours), on the fish catching technique, and on fish temperature. It was also found that fast swimmers, for example trout, undergo *rigor mortis* faster but for a shorter duration than slow swimmers like carp.

In those fish which are in good condition (well-nourished) *rigor mortis* is more intensive. Fish put to death just after removal from the water reach a state of *rigor mortis* later than those fish which died after a long agony. In the case of carp put to death just after capture *rigor mortis* begins after 48 hours, but if the carp died after a long agony it sets in after 24 hours (at 0°C).

Unnecessary and rough handling of the fish can shorten the time of occurrence and duration of *rigor mortis*. Such treatment causes stress in live fish.

Fish body temperature is a decisive factor in the onset and duration of the *rigor mortis* process. The higher the temperature the sooner it begins and the faster it ceases. This is evidenced by enzymatic reactions whose speed increases with increased temperature. At high temperatures it results in greater changes in proteins, the latter causing higher loss of tissue juices, e.g., during processing. Usually, the later *rigor mortis* begins and the longer it lasts, the longer are the storage life of the fish and its use for consumption.

2.2.3 Autolysis

On the death of the fish, a complicated biochemical process starts, leading to a decomposition of basic compounds of tissues which takes place under the influence of enzymes. This decomposition involves proteins, lipids and carbohydrates. Its intensity is not the same for all compounds and the decomposition of one can influence the decomposition of the others.

The quality of fish as a raw material for consumption or for processing depends largely on proteolysis, that is, the decomposition of proteins. This process follows rigor mortis. The final products of protein hydrolysis, under the influence of enzymes, are: amino-

acids and other low-molecular substances which have an impact on the sensory features of fish. A similar situation concerns the products of lipid autolysis: thus autolysis cannot be qualified as a phase in the spoilage process.

During autolysis, great changes occur in the structure of muscle tissue which becomes softer, and very often falls into layers along the myosepts. In small fish, perforation of the belly occurs. From the technological view, it is negative because the proteolysis process leads to a decrease in the capacity of tissue to retain tissue juice, resulting in toughness of texture of the final product. The degradation of proteins creates ideal conditions for the growth of spoilage bacteria.

2.2.4 Microbiological decomposition

The muscle tissue of live fish is generally sterile but bacteria thrive in the alimentary tract and on the skin, and from there they penetrate into the muscles; for example, through the blood vessels. This process is further favoured by structural changes in the tissue as a result of *rigor mortis* and autolysis. Bacteria are able to decompose proteins, but products of proteolysis such as amino-acids and other low-molecular nitrogenous compounds provide better nourishment. Thus it was found that, due to lower content of these substances, freshwater fish tissue undergoes microbiological decomposition more slowly than marine fish tissue. Micro-organisms cause decomposition of not only proteins but other compounds containing nitrogen, lipids to peroxides, aldehydes, ketones and lower aliphatic acids. However, the decomposition of nitrogenous compounds occurs much faster than in the case of lipids.

Compounds such ammonia, hydrogen sulphide and mercaptans, indole, skatole, etc., are the final products of microbiological spoilage of fish, which produces an unpleasant and then disgusting flavour.

Penetration of bacteria into fish tissue and microbiological decomposition begins with autolysis and these processes are practically parallel. However, their rate and intensity strictly depend on the storage temperature. Low temperature strongly inhibits the activity of micro-organisms in which case the autolysis process dominates.

2.3 Indicators of Fish Freshness

Freshwater fish, as other fish species, are raw material which fast deteriorates. This implies that both the producer and the consumer are very often exposed to the risk of buying fish which is not fresh or has even deteriorated. Knowledge of the average shelf life for individual fish species - depending on storage conditions - is a basic principle applied in the food - and the fish - industry. Effective, objective and repeatable methods for evaluation of raw material freshness should be specified, but attempts so far are only now showing positive results. Thus, sensory analysis is the main method of evaluating fish freshness. It enables differences in texture, flavour, and taste to be determined, and subsequently the usefulness of the raw material. Sensory properties change during storage from the desired very high standard, through neutral or average, and finally to undesirable or disgusting. It is generally assumed that prior to disappearance of desirable features the fish is considered to be fresh, while the appearance of undesirable or disgusting features disqualifies the raw material. The

most difficult step is to determine an intermediate state in which the fish is not entirely fresh. Sensory analysis is thus carried out on raw fish and cooked fish. Flavour, appearance and state of abdominal cavity (for not eviscerated fish) are the main indicators of quality in the case of raw fish. For cooked fish, smell is the most important indicator. These problems are covered in section 6.5.2 Quality control.

3. PRELIMINARY PROCESSING OF FRESHWATER FISH

3.1 Requirements Related to Freshwater Fish Processing

Freshwater fish processing, like the processing of other food raw materials, should:

- assure best possible market quality
- provide a proper form of semi-processed of final product
- assure health safety of products
- apply the most rational raw processing method
- reduce waste to the extent possible

Due to its chemical composition, fish is a perishable raw material. Fish flavour and texture change rapidly during storage after death. It is thus advisable in freshwater fish processing to keep the fish alive as long as possible. Actions focusing on quality assurance also involve transport and storage/depuration of the fish awaiting processing (described in section 3.2).

In order to reduce the bacterial processes, immediately on death fish should be deheaded, gutted, washed and chilled in order to inhibit unfavourable enzymatic and microbiological processes. If fish is not sold fresh, preservations methods should be applied in order to extend shelf life. These could include freezing, smoking, heat treatment (sterilization, pasteurization, etc.).

Another aspect of fish processing is to give the product a form which is attractive to the consumer, e.g., skinless fillet or deheaded fish with fins removed.

The third main goal of fish processing is high product quality and extended shelf life.

Fresh fish can be stored only for the short time that processing technologies allow for the storage life of fish to be extended without significant loss of quality.

Fish processing must ensure full health safety of fish products and proper sanitary conditions as well as selection of a process (e.g., sterilization, pasteurization) which render impossible the development of harmful micro-organisms and toxins. High quality products which are safe and satisfy the consumer can be reached by compliance with processing parameters, from the start of the operation to the distribution of the final product.

Appropriate processing should enable maximal use of raw material and thus contribute to increased economic profitability. This is a basic approach in modern industry. A filleting operation offers a classic example of such an approach in which, apart from the fillets, minced meat can be produced from the waste material and the remainder sold as animal feed.

Thus the process results in practically no unused waste material. However, achievement of this goal essentially requires that mechanization be introduced into processing, albeit on a small scale. At the same time, it is noted that production of value added products is obviously the basis of processing profitability and can be a decisive factor for the survival of many fish processing plants, especially the small ones.

Fishing, processing, transportation and sale of fish products are links in a complete processing chain. Each has its own importance but only together can they form an inseparable process to provide the customer with a top quality product.

3.2 Handling of Freshwater Fish before Processing

The quality of the raw material and its usefulness for further utilization in processing is affected by the fish capture method. Unsuitable fishing methods e.g., catching too many fish in one haul, cause not only mechanical damage to the fish, but also create stress and the conditions which accelerate processes which begin after fish death.

In many countries consumers are used to buying live fish: this assures the highest quality. This habit takes different forms, e.g., the consumer buys live fish, for instance carp or trout and processes it at home. Very often the fish bought live can be partly processed by the shop assistant; for example, it can be filleted. In some restaurants the customer can choose the fish from an aquarium and have it prepared for consumption. Thus the tradition, the quality, and the resultant price, constitute the reason why the preparation of fish for transportation, and the transportation itself, are the preliminary operations of processing of freshwater fish like trout, carp, eel, etc. However, producers should remember that not all fish are suitable for transportation alive. Therefore, just after fishing, fish should be sorted and only those in good condition, healthy and not damaged be destined for sale as live fish. Fish so classified is first conditioned in water of appropriate quality. The conditioning process reduces stress, inhibits metabolism and at the same time food remains are removed from the alimentary ducts and the oxygen demand reduced. During the conditioning process fish is not fed which further inhibits metabolism and also limits the excretion of ammonia and carbon dioxide. In the short conditioning process 1 m^3 of water is sufficient for 50-60 kg of carp, 30-40 kg of pike, 20-25 kg of trout or pike-perch.

Water provided for conditioning must be properly oxidized.

For example, in the case of 1 kg of fish at a temperature of 10°C the oxygen demand is: eel 25 mg, carp 45 mg, pike 50 mg. Young fish need more oxygen than older fish. Oxygen consumption depends also on the liveliness of fish. The amount of oxygen dissolved in water depends on water temperature which should be rather low. But for stenothermal species such as carp water temperature should be not less than 10-12°C in summer and 5-6°C in spring and autumn. Optimal temperature for conditioning and transportation of trout is 5-6°C in summer and 3-5°C in spring. During winter fish tolerates temperatures of 1-2°C.

Nowadays, special tanks with aeration system and often with cooling and filtering (activated coal, biological filters) systems are used for transportation of live fish. In simple solutions water is cooled by ice. Cooling is especially important during summer and in transportation over long distances. If all parameters, i.e., temperature, oxygenation, are

properly maintained, and when the temperature does not exceed 10°C, the weight loss varies from 1 to 6%, and about 10% of carp and 20% of trout die during a six-day transportation in winter. At present, large valuable fish species are transported via air in which case they are placed in big plastic bags with aeration system.

3.3 Equipment for Preliminary Processing of Freshwater Fish

Preliminary processing of freshwater fish usually consists of the following steps or unit processes: evisceration, deheading, scaling, cutting of fins and belly flaps, slicing of whole fish into steaks, filleting, skinning, grinding of skinned fillets and different combinations of the above (Figure 3.1).

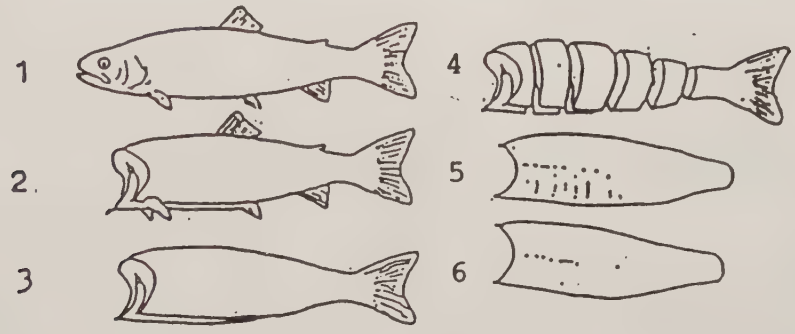


Figure 3.1 Major forms of preprocessed fish:

1 - whole fish,
2 - gutted fish without head,
3 - gutted fish without head and fins,
4 - sliced whole fish after deheading and evisceration,
5 - fillet with ribs, and
6 - fillet without ribs, with or without the skin.

The products of preliminary processing can be sold or further processed to obtain value added products. In freshwater fish processing, particularly species such as perch, pike-perch and the cyprinids, the processing steps described above are executed manually with a wide variety of knives. Efficient preparation of fish is important when top quality, maximum yield and highest possible profits are to be achieved. This is important when fish is to be exported. Efficient fish preparation is a skill only be acquired with practice. Several perfectly acceptable methods for cutting any fish exist; they may often give the same yield and similar end-products. In the future, the level of mechanization of fish processing in small processing plants will increase due to the constant pressure to reduce production costs and improve economic performance.

The present level of mechanization is low which results from the overall limited production, seasonal availability of the raw product and lack of inexpensive, efficient mechanical equipment adaptable for processing of various fish species.

In practice, most freshwater fish processing is done in small processing plants (with the exception of salmon and trout processing), usually supplying products for local or nearby markets. Manpower capacity in such plants varies, usually not exceeding 10-20 employees. In addition to freshwater fish, frozen marine fish may be processed in the same plant.

3.3.1 Stunning of fish

In many freshwater species the method of stunning is critical for final product quality because prolonged agony of fish causes production of undesired substances in the tissue. Oxygen deficiency in blood and muscle tissue results in accumulation of lactic acid and other reduced products of catabolic processes and consequently in a paralysis of the neural system. Red spots appear on the surface of the skin and in the muscle tissue near the backbone; these reduce quality.

Stunning of freshly caught fish or fish delivered live to a processing plant is best done with an electric current. First, the fish are placed in a tank of water and an electric current is then passed through the water to stun or kill the fish. Live fish are also slaughtered by cutting the aorta and bleeding to death when technological or ritual reasons require the removal of blood from the tissue before further processing.

In some plants, water in the fish tanks is saturated with carbon dioxide which renders the animals unconscious or dead.

3.3.2 Grading

The processing sequence starts from grading the fish by species and size. Sorting by species or on the basis of freshness and physical damage are still manual processes, but grading of fish by size is easily done with mechanical equipment. Mechanical graders yield better sorting precision for fish before or after *rigor mortis* than for fish in a state of *rigor mortis*.

Size grading is very important for fish processing (i.e., smoking, freezing, heat treatment, salting, etc.) as well as for marketing. Automated sorters are rarely used in small plants processing freshwater fish because the raw product is usually already sorted on delivery and because of their high costs.

Automated grading is 6-10 times more efficient than manual grading. The sorting speed of different graders varies and depends on the type of device and size of fish sorted. Sorting capacity is 1-15 t/hour, and usually into three size groups.

A combination of conveyor belt and automated sorter shown in Figure 3.2 is used by fish processing plants in the USA. This machine has an interesting design: two smooth rotating rollers are installed above the surface of the conveyor belt and the distance between the rollers and belt can be adjusted according to the maximum thickness of the sorted fish. Thinner animals fall off the belt while the thick ones are retained on it until the end of line. Therefore, one device serves simultaneously as a grading machine and a conveyor.

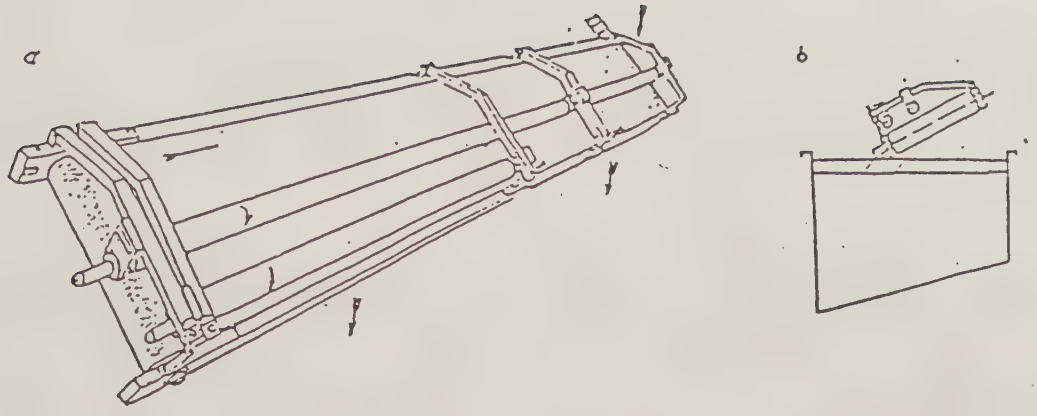


Figure 3.2 Combination grading machine-conveyor belt:
a - general view, b - cross-section

Most commonly used grading machines consist of a series of compartments connected by slits of varying size (Figure 3.3) with rotating rollers or conveyor belts arranged in a V-shape (Figure 3.4). In such devices fish are sorted according to the maximum thickness which is highly correlated to fish length. The size range to be sorted is easily adjusted.

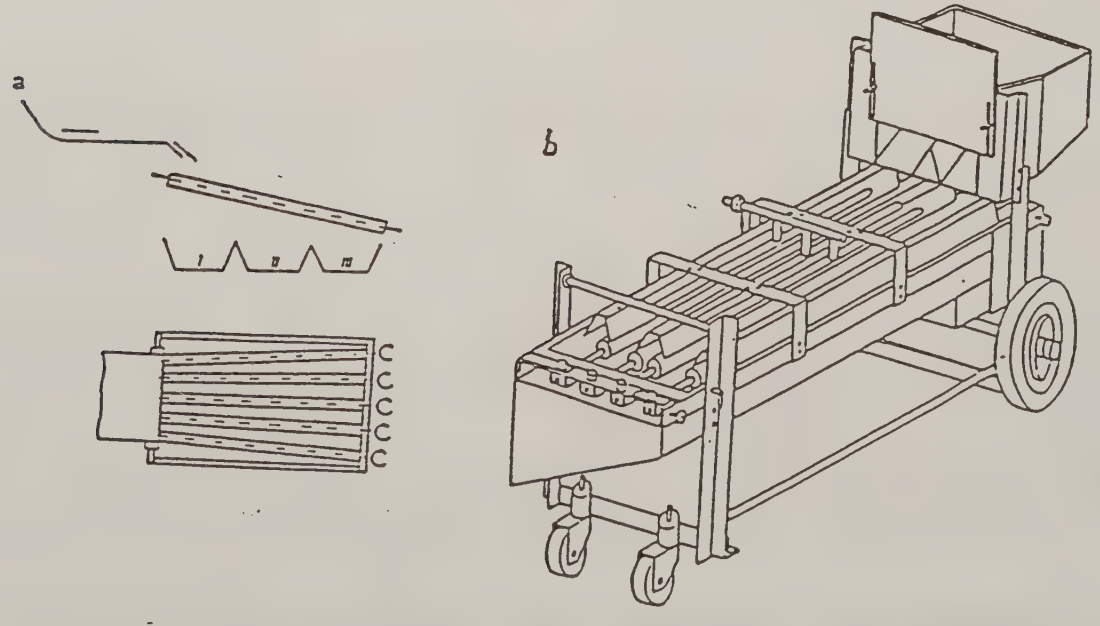


Figure 3.3 Grading machine with a fan shaped arrangement of rollers:
a - scheme, b - general view.

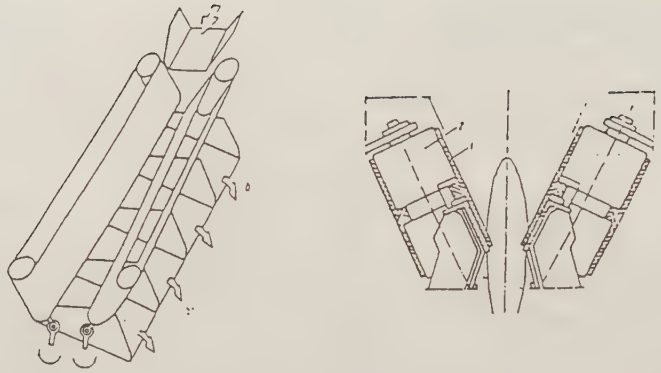


Figure 3.4 Slit grader consisting of two conveyor belts arranged in a V-shape; 1 - rubber belt, 2 - rotating wheel

3.3.3 Removal of slime

Slime accumulating on the skin surface of dying fish is a protection mechanism against harmful conditions. In some freshwater species slime constitutes 2-3% of body weight. Slime excretion stops before *rigor mortis*. Slime creates a perfect environment for micro-organism growth and should be removed by thorough washing. Eel, trout and carp require special care with regard to slime removal. Even small amounts of slime, which frequently remain after manual cleaning, result in visible yellowish-brown spots (particularly in smoked eel).

Drum-washing with a horizontal rotation axis does not remove slime from some fish, e.g., eel. Eel are best washed in machines which originally serve as scalers (Figure 3.5a, b). The device is loaded with 30 kg of eel and several kilograms of salt, and after about 2-3 minutes the slime is completely removed from the fish skin. This procedure is more efficient than manual washing.

Slime can be removed from eel, trout and other freshwater species by soaking fish in a 2% solution of baking soda and then washing in a cylindrical rotating washer.

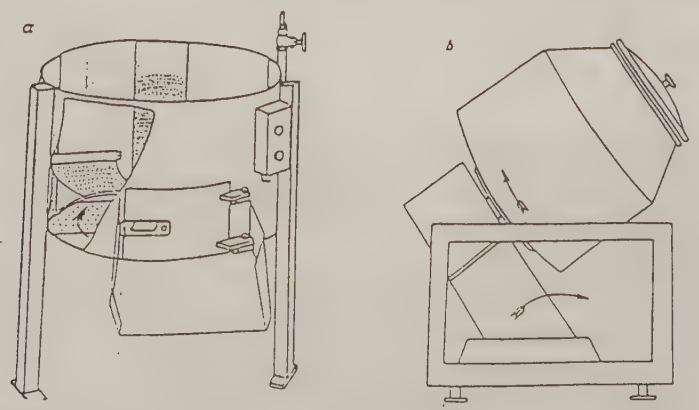


Figure 3.5 a. Vertical drum scaler with rotating bottom,
b. Rotating cylindrical scaler with a tilted axis of rotation (adapted from a cement mixer).
Both machines can be used for slime removal.

3.3.4 Scaling

Many freshwater species are routinely scaled; this is extremely labour-intensive when done manually. Some sources estimate that manual scaling of larger animals requires almost 50% of the total time necessary to produce headed and gutted fish without fins. Fish destined for skinning and filleting or to be smoked or minced in mincing/deboning separator is not scaled. Tools used for manual scaling are shown in Figure 3.6. Tools are moved over the body of fish from tail fin towards the head, pulling out the scales.

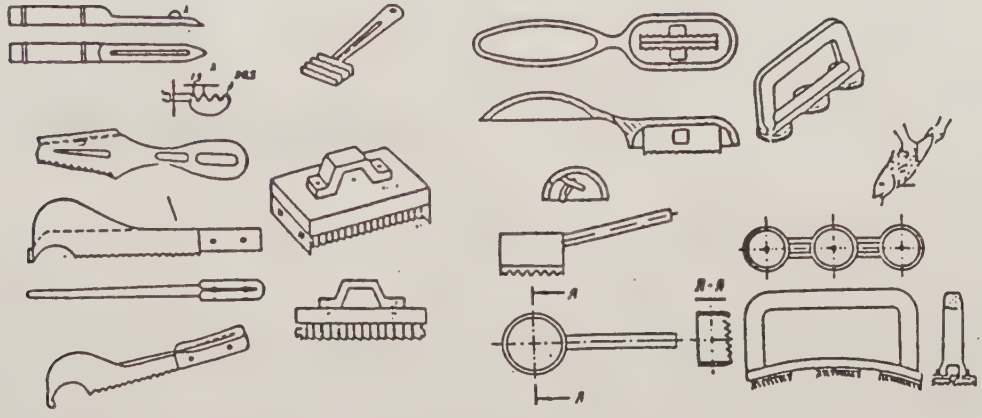


Figure 3.6 Tools used for manual scaling

Fish such as perch, bream, pike-perch and carp, are particularly difficult to scale manually. One method includes blanching of fish for 3-6 seconds in boiling water and then scaling by hand with motions perpendicular to the long body axis. Mechanized and power-assisted hand-held scalers are commonly used in small processing plants (Figure 3.7).

Electrical hand-held scalers simplify and speed up the scaling procedure. They are most commonly used for secondary scaling of fish which has left the automated scaling device 80-90% free of scales. Use of electrical hand-held scalers reduces labour intensity and assures complete elimination of scales. The power-assisted tool shown in Figure 3.7 consists of a cylindrical rotating scraper of 30-40 mm diameter powered by an electric motor and connected to it with a flexible rod. The vertical cylindrical scaler with rotating bottom (Figure 3.8 a) and fixed side wall is widely used in small fish processing plants. Fish (usually 30-40 kg) is loaded from the top and unloaded through the door in the side wall. Scales catch on small contoured slits cut in the bottom and side wall of the device, and are thus pulled out of the skin. The same machines can be used for slime removal. Cement mixers are often utilized for scaling after the original cylinder is replaced with a 120-l drum made of stainless steel, with punctured contoured slits of 10 mm diameter (Figure 3.5 b). In addition to devices which have been specifically designed for scaling, a variety of automated tools can be employed, e.g., vegetable peelers. However, their use may result in mechanical damage to the fish even after modifications (Figure 3.8 a).

A semi-automated device, shown in Figure 3.8 b, is used for scaling larger fish; fish is manually passed over the rough surface rotating drums which have contoured slits of 3-4 mm depth. One worker can scale 10-20 fishes/minute (scaling speed varying with species). Special protective gloves must be worn during this procedure.

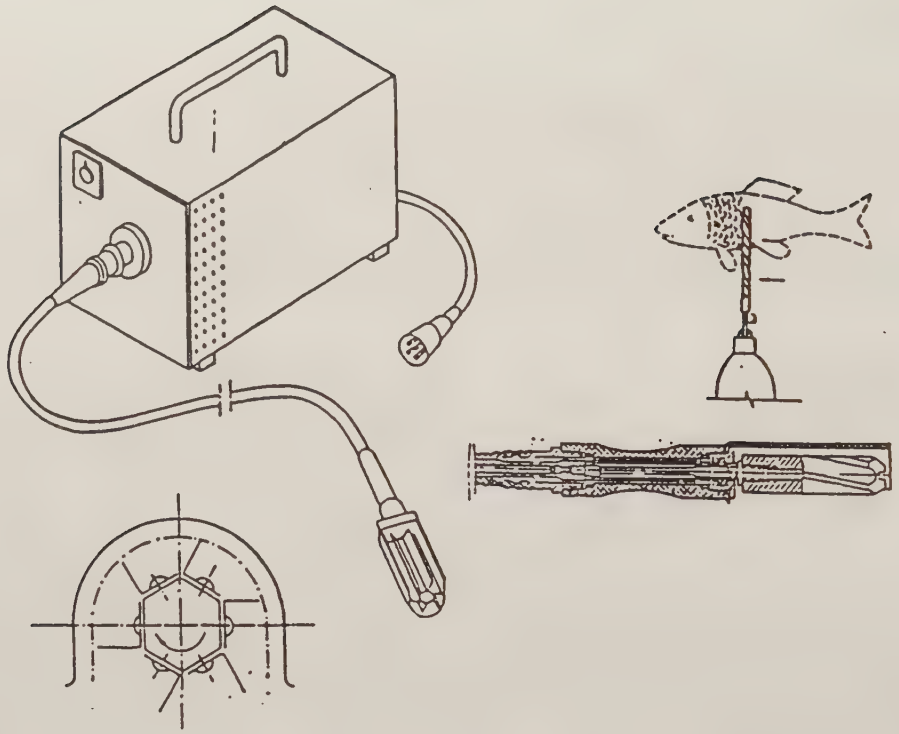


Figure 3.7 Electrical scaler

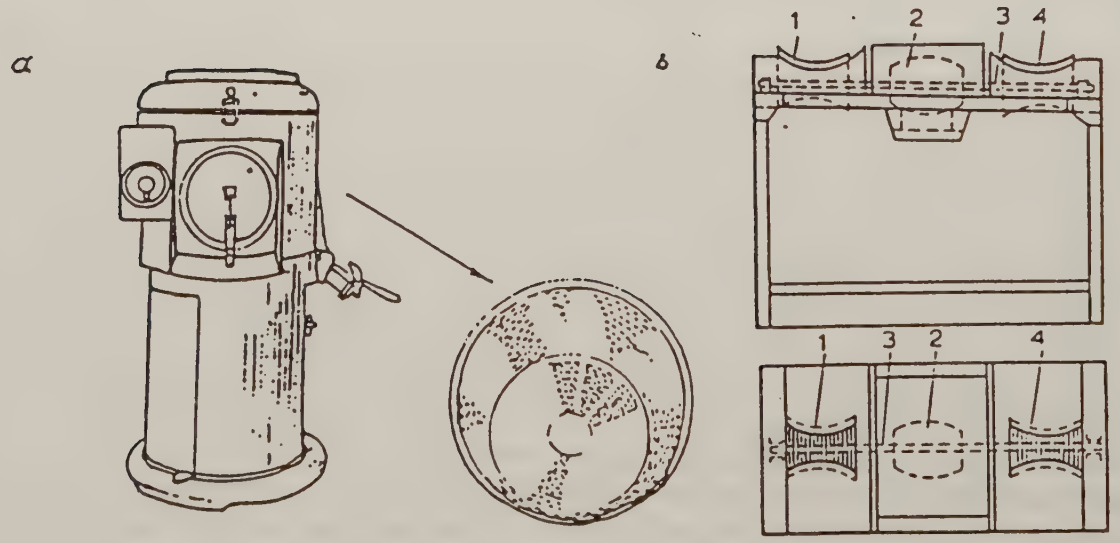


Figure 3.8. a. Scaler modified from a mechanical vegetable peeler (rotating bottom),
b. Drum scaler with two processing lines; 1.4 - rough surface rotating drum, 2 - engine, 3 - drive shaft

Various scalers are designed on the same principle. The processing time of a cylindrical rotating scaler with the horizontal rotation axis (Figure 3.9) is from 2 to 7 minutes depending on the species and size as well as on the type of slits on the surface of the drum and the rotational speed. The total weight of fish loaded in one run rarely exceeds 30-60 kg.

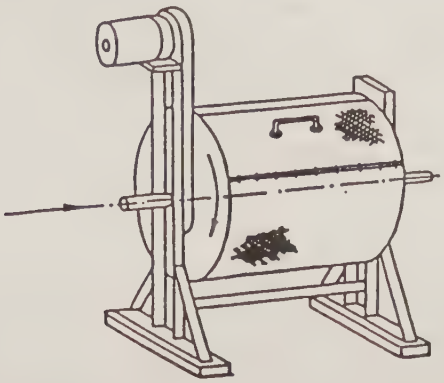


Figure 3.9 Cylindrical scaler with horizontal rotation axis

Another kind of cylindrical scaler with a horizontal rotation axis can be periodically tilted during a scaling cycle which causes fish to tumble inside the drum, and consequently scales more efficiently. In some fish species, the scales can be removed from fish with a pressurized stream of water while fish is placed inside the scaler drum. The drums of such devices are made either of stainless mesh with rough edges or of stainless sheets perforated with contoured slits which detach the scales. Water has to be injected into the drum for the machine to operate. Less common are cylindrical scalers with a continuous operating cycle.

3.3.5 Washing

Washing is intended primarily to clean the fish and to remove accumulated bacteria. The effectiveness of the washing procedure depends, inter alia, on the kinetic energy of the water stream, ratio of fish volume to water volume and on the water quality. A proper fish:water volume ratio for achieving the desired level of cleanliness is 1:1, however, in practice more water is usually used (twofold). Washing of gutted and headed fish should be done on termination of the processing operation. To improve the effectiveness of the cleaning procedure, various mechanized scrubbing devices are utilized which can remove up to 90% of the initial bacterial contamination. Potable water is used for washing in freshwater fish processing plants.

The following washers are commonly used: vertical drum (Figure 3.10 a), horizontal drum (Figure 3.10 b) and a combination washer-conveyor belt (Figure 3.10 c).

The operation cycle for these machines is 1-2 minutes. The vertical drum washer is frequently used because of its conveniently small size. The most common is the horizontal tumbler washer. A rotating perforated drum constitutes the main component of this device; the drum is usually 2-4 m long, with round holes 10 mm in diameter. Inside the drum there are metal or rubber bars which facilitate tumbling and mixing of fish. Rotation of the drum, its tilted axis and the arrangement of internal bars result in a movement of fish towards the outlet of the device. Washing is continuous and is accomplished by spraying pressurized water through the perforated pipe installed inside the drum. Dirty water collects in the waste basins.

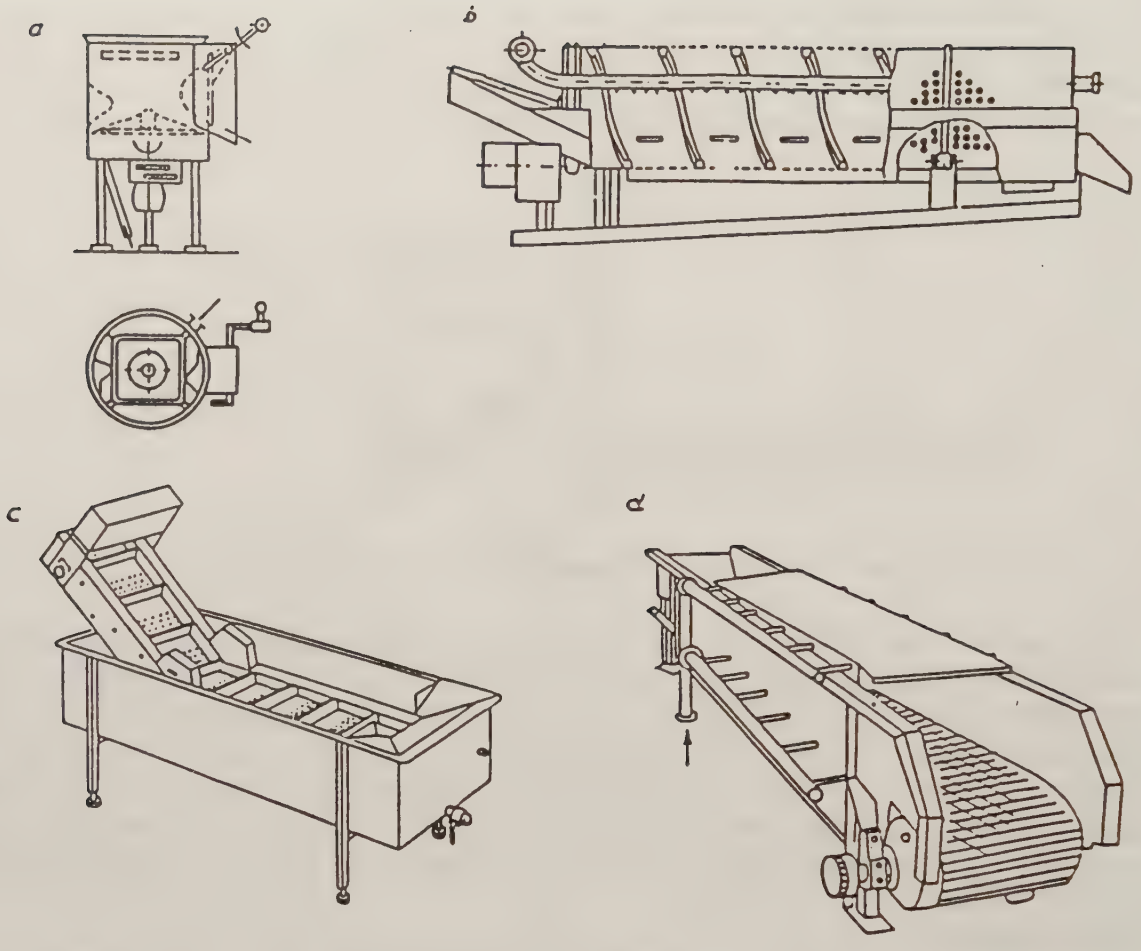


Figure 3.10
a. Vertical-axis drum washer
b. Horizontal-axis drum washer
c. Combination washer-conveyor belt
d. Conveyor with a water spraying system (belt made of metal mesh) used as a washer

The mechanized washers described can be used to process whole fish, deheaded and gutted fish as well as boneless fillets because the washing action generates no physical damage to the product. Due to their continuous operating cycle, horizontal-axis drum washers are particularly suitable for production lines requiring constant product flow. A combination washer-conveyor is less popular but can serve to separate fish from ice: ice, having lower density than water, floats to the water surface from where it is removed, while fish falls onto the meshed conveyor and leaves the washing basin. Although there is an additional water jet at the exit from the water basin, the effectiveness of washing in this washer is lower than in the drum washers; fish on the conveyor belt is not exposed to scrubbing which is so important in the tumbler washers. The meshed conveyor (stainless steel or plastic mesh) with a water spraying system shown in the Figure 3.10 d, can also serve as a washer but its use is limited.

3.3.6 Deheading

The head constitutes 10-20% of the total fish weight and it is cut off as an inedible part. Although many mechanized deheading machines had been developed for processing

marine fish, freshwater fish are usually deheaded manually. The main reason is the lack of inexpensive equipment offering minimal tissue loss during this procedure. Different cutting techniques used for deheading are shown in Figure 3.11.

A cut around the operculum, a so-called round cut, results in lowest meat loss. This technique is 4-5% more efficient than the straight cut commonly used in mechanized systems. The contoured cut, which runs perpendicular to the fish's backbone and then at an angle of 45° (Figure 3.11 II), is also advantageous. This particular deheading technique is used when fillet, mainly boneless and skinned, is the final product. The head is removed with the pectoral bones and fins.

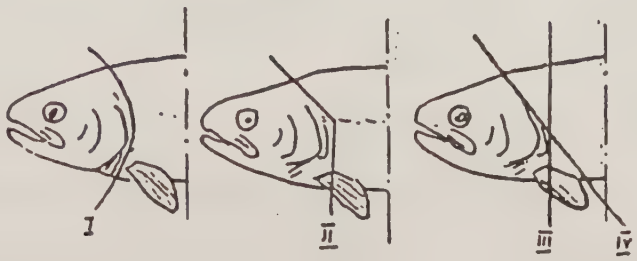


Figure 3.11 Cutting techniques used for deheading of freshwater fish:
I - round cut, II - contoured cut, III - straight cut, IV - slant cut

In small freshwater fish processing plants, small fish are frequently deheaded manually. Deheading of larger fish requires much more effort and automated heading devices are essential. Unfortunately, a single deheading machine which would cover a broad spectrum of fish sizes, i.e., 20-110 cm, does not exist. An average deheading device can usually be used to process fish for which a difference between minimum and maximum length does not exceed 30-40 cm. The cutting elements used in the deheading machines are either disc, contoured, cylindrical knives, band saws or guillotine cutters. A machine operator adjusts the position of the cutting element according to the fish size. Thus the amount of meat lost during the deheading procedure depends not only on the type of head cut but on the experience and skill of the operator. The speed of a deheading device depends on the size of fish processed and is usually 20-40 fish/minute.

In some plants, simple - and sometimes rigged by an amateur - deheading devices are used which can potentially cause severe physical damage to the operator's hands. It is very important to examine safety problems associated with handling of the device before making a final decision about its purchase.

The deheading machine with a guillotine cutter is used for deheading larger freshwater fish (Figures 3.12 a, 3.12 b); cutters are changed according to species and size range. Economical cuts such as contoured cut or cut around operculum can be performed by changing the cutters.

In one type of deheading device with cylindrical rotational saw (Figure 3.12 b) the round cut is used. The most commonly utilized saw sizes are 12, 15 and 18 cm in diameter; saw size is adjusted to the fish species and size. The simplest designs are represented by the deheading machines with a circular saw (manually operated by pushing the fish under the saw - Figure 3.13 a) and with a disc saw which also acts as a guillotine (Figure 3.13 b).

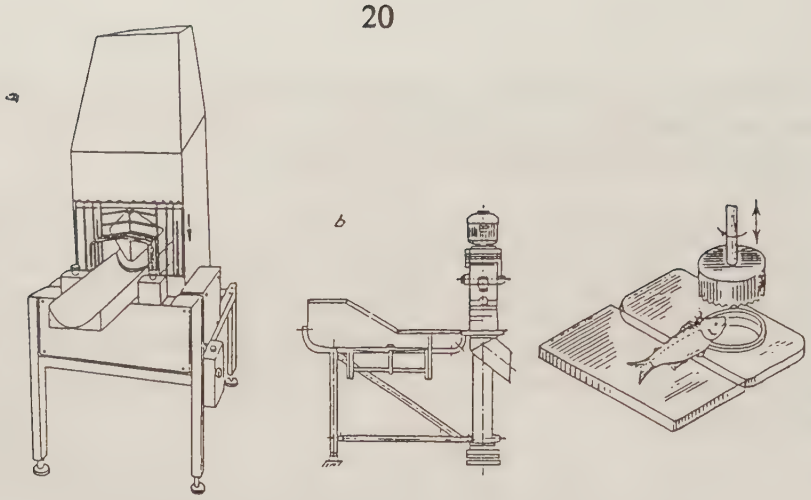


Figure 3.12 a. Deheading machine with guillotine cutter, suitable for larger fish (contoured or round cut)
b. Deheading machine with a cylindrical rotational saw (round cut)

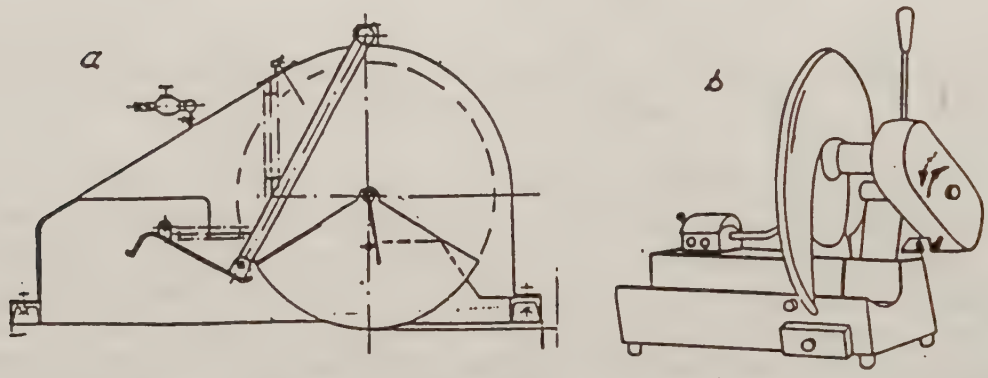


Figure 3.13 a. Deheading machine with a circular saw, operated manually (straight cut),
b. Deheading machine with the disc saw and guillotine action (straight cut)

3.3.7 Gutting

The purpose of gutting is to remove those fish body parts most likely to reduce product quality, as well as to remove gonads and sometimes the swim bladder. Evisceration of freshwater fish is labour-intensive and usually performed by hand. Gutting consists of cutting down the belly (fish may be deheaded or not), removal of internal organs, and, optionally, cleaning the body cavity of the peritoneum, kidney tissue and blood. Fish is cut longitudinally up to the anal opening, and special care is taken to avoid cutting the gall bladder. This procedure is performed on a table made of special material which is hard, easy to wash and does not absorb fluids. The table surface should be frequently rinsed and periodically disinfected.

A specialized gutting work station shown in Figure 3.14, allows to safely cut fish down the belly (used mainly during processing of trout), remove the guts by vacuum suction and quickly wash and rinse the body cavity with a rotational brush and a water spray, including kidney tissue removal.

Simple systems consisting of rotating brushes and water sprays are widely used (Figure 3.14 a). They facilitate the work and increase the product quality. Protective gloves, periodically disinfected and replaced, should be worn during gutting, especially when mechanized devices are used.

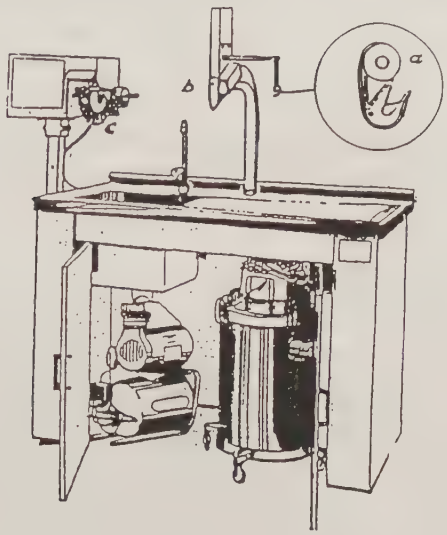


Figure 3.14 Gutting work station:
a. cutting down belly with a safe cutting element,
b. removal of guts with vacuum suction,
c. washing and rinsing of body cavity with rotational brush

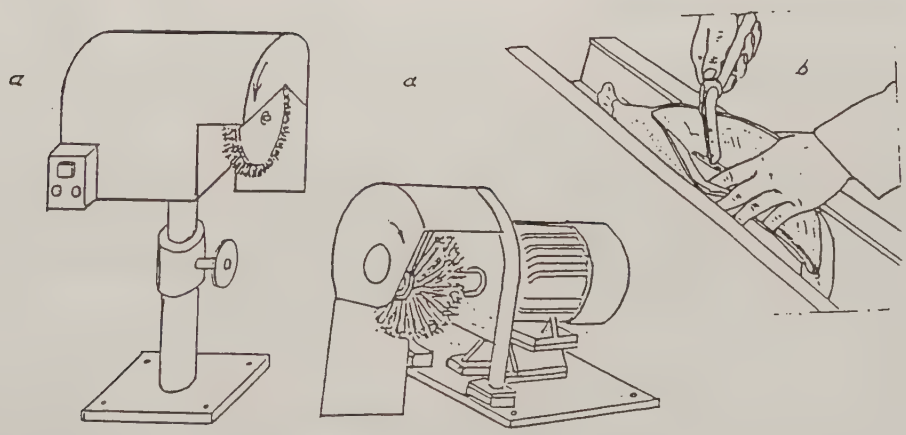


Figure 3.15 a. Rotating brushes used to clean body cavity and to remove kidney tissue (with and without adjustable height),
b. hand-held vacuum suction tool for kidney removal and cleaning of body cavity

It is likely that the vacuum suction tools (kidney and blood removal) used to clean the body cavity in processing salmonids, will find an application for other freshwater fish species (Figure 3.15 b).

Gutting machines for processing trout, eel and a couple of other species, have been constructed in several countries, but high price renders them unsuitable for smaller plants. The cutting of the body cavity, removal of guts and kidney tissue with brushes and vacuum suction can be performed in these multi-application machines.

Some freshwater fish species, in particular bream, perch, roach, carp of length 20-40 cm, can be deheaded and gutted in a machine which employs a so-called American cut (Figure 3.16). Although the technological efficiency of this cut is not high, the processing speed reaches up to 40 fishes/minute.

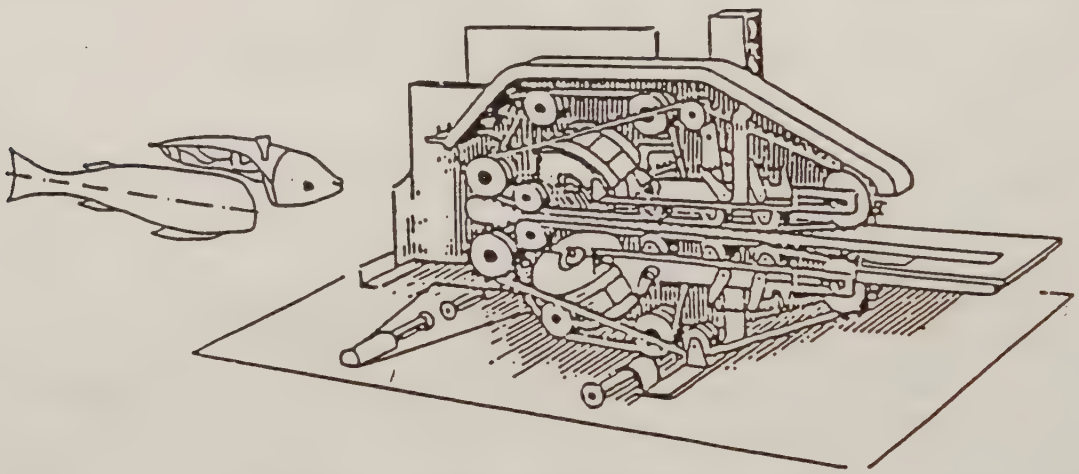


Figure 3.16 Deheading and gutting machine

3.3.8 Cutting away the fins

Manually cutting away the fins with either a knife, special mechanized scissors or rotating disc knives, is a labour-intensive and strenuous operation when handling larger fish. This operation is most frequently done after gutting during the production of deheaded whole fish and fish steaks. An automated device consisting of the rotating disc knives with a slit cutting edge, powered by electric motor (Figure 3.17), facilitates and speeds up the fin removal procedure. The knife slot has a horizontal opening through which the dorsal and ventral fins are passed manually and cut out.

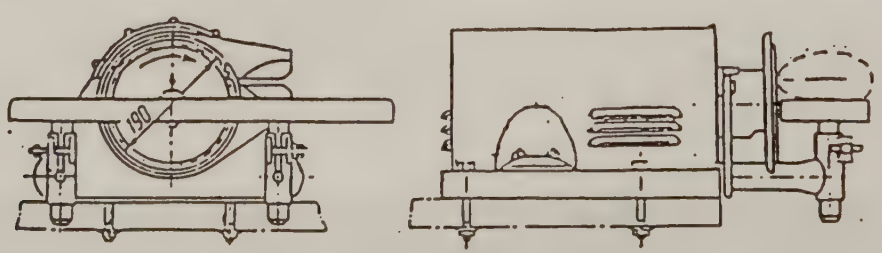


Figure 3.17 Equipment for cutting out the fins, employing a disc knife

3.3.9 Slicing of whole fish into steaks

Slicing of deheaded whole fish into steaks with a cut perpendicular to the animal's backbone is a very common fish processing method. The high technological efficiency of this processing technique compared to filleting and automated cutting into pieces, makes it popular with retail markets and the canning industry. The fish pieces obtained average 2.5 to 4.5 cm thick.

Smaller and medium size fish are cut manually in concave basins which have slots evenly spaced to facilitate slicing into steaks of equal thickness. A knife or a band saw is used to slice the fish. Sometimes a band saw is used to remove the head and cut the body into two parts, one retaining the backbone.

Larger fish, particularly cyprinids, which have a massive and more solid backbone, need slicing mechanically. Numerous designs of such machines exist (Figure 3.18 a,b,c), and generally utilize multiple rotating circular saws attached to the drive. The distance between the saws as well as the elements moving the fish along the line can be adjusted. The deheaded whole fishes are placed into an automated cutter oriented so that the last piece cut has a prescribed length. A mechanized cutter can process 20-40 fishes/minute, depending on the fish size.

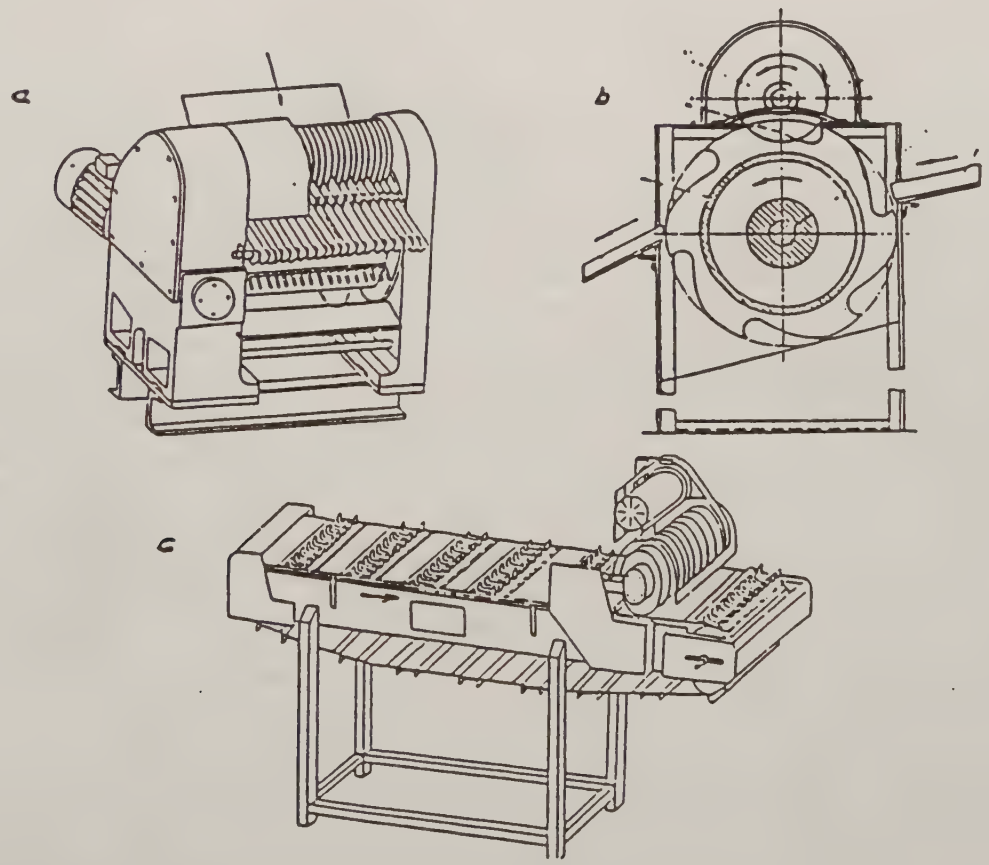


Figure 3.18 a. Cutter used for slicing whole fish into steaks,
b. Cutter with a drum-type loading system,
c. Cutter with a loading conveyor belt.

3.3.10 Filleting

A fillet which is a piece of meat consisting of the dorsal and abdominal muscles has been a most sought-after fish product in the retail market. Filleting efficiency depends upon fish species, its sex, size and nutritional condition.

Manual filleting is very labour-intensive and largely depends on the skills of the workers. However, filleting of freshwater fish is not as widely applied as for marine fish.

Filleting machines for processing marine fish are quite costly and are not suitable for freshwater species; in the case of trout, for example, expensive multi-function devices have been designed which are not used in small processing plants.

Some fish markets sell fillets of carp, perch, pike-perch and smoked single or block fillet of trout. Besides fillets, other forms are processed, e.g., block fillet retaining some bones (boned fillet) and the simplest type of processed carp which is the deheaded whole fish cut into two halves, one retaining the backbone. Restaurants and fish stores use simple tools to streamline the manual longitudinal cutting of fish. The same result is obtained by using a filleting device with a single rotating disc knife and two conveyor belts (Figure 3.19 b).

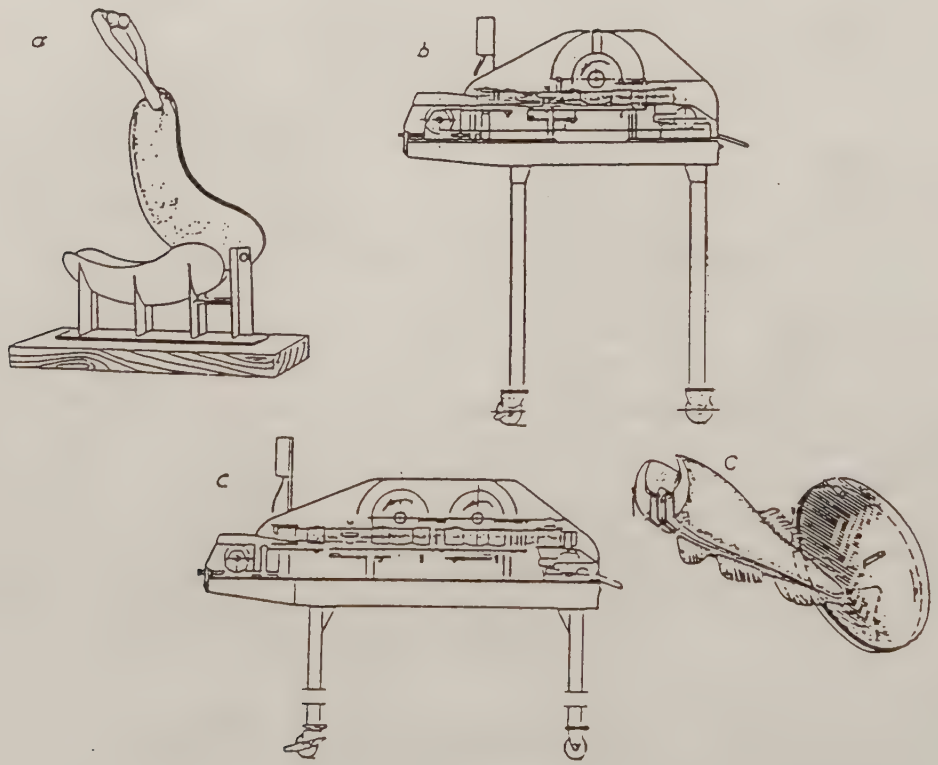


Figure 3.19
a. Manual tool for cutting whole fish into two parts (backbone remains),
b. Filleting machine with conveyors, used for cutting fish into two halves (backbone remains),
c. Filleting machine with a conveyor, used in production of boned fillet without the backbone

Manual filleting and deboning are time- and labour-consuming procedures, and are usually carried out using simple and inexpensive machines. In small plants processing freshwater fish, a type of machine which separates fillets and bones, sometimes with part of the backbone left near the head region, is increasingly more common.

The demand for freshwater fish fillets increases interest in simple and inexpensive single-purpose machines for filleting of deheaded and/or gutted fish. Different species (trout, perch, pike-perch, pike, cyprinids, etc.) can be processed in these devices as long as they are in the same size range. The remaining ribs and pin bones are manually removed from the fillets, and sometimes, as in case of cyprinids, perch and roach, the bones are cut by machine as shown in Figure 3.20.

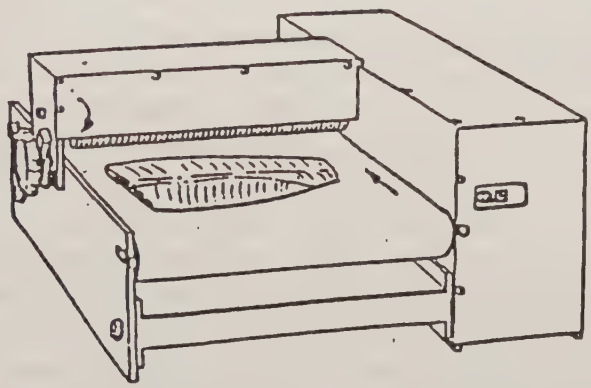


Figure 3.20 Machine used for cutting ribs in the boned freshwater fish fillet

The simplest filleting machine (Figure 3.21) for gutted and deheaded fish has two disc knives set from each other at a distance equal to the thickness of the fish's backbone. Filleting speed of these devices is 30-40 fishes/minute: they are efficient and the quality of the final product is good. However, manual processing yields better results. The size range of the processed fish is 20-45 cm. Machines of different design and with bigger knives are used for processing larger fish (Figure 3.19 c). Filleting devices are produced in several countries (Germany, Poland, Russia) and are increasingly used in small processing plants.

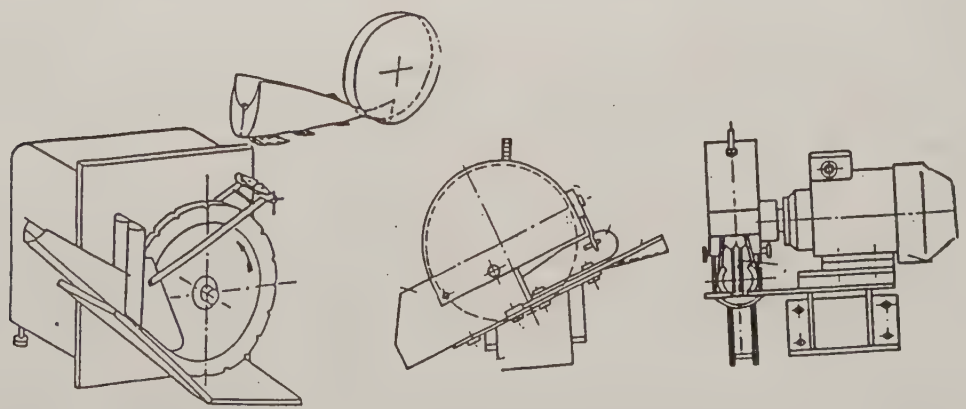


Figure 3.21 Filleting machine used for production of boned fillets from freshwater and marine fish

Meat left on the fish's backbone after filleting can be recovered to a high degree using a meat-bone separator (Figure 3.23). Up to 50% of the total mass of processed backbones can be recovered as meat.

Boned fillets with ribs are subsequently processed by cutting the ribs in an automated system consisting of several disc knives 100-200 cm in diameter, set on a drive every 4-5 mm. After cooking, particularly after frying, the tiny cut rib pieces are barely noticeable and cause no discomfort during consumption. In the machine used for cutting ribs (Figure 3.20), the boned fish fillets lie skin-down on a conveyor belt which drives them under the disc knives; the ribs are cut and incisions of determined depth are made in the meat.

3.3.11 Skinning

Only recently has skinning of freshwater fish fillets been introduced into processing plants. Manual fillet skinning is labour-intensive and difficult; a sharp knife and flat board made of metal or plastic are needed. The fillet is placed on the board skin-down, the meat is grasped in the left hand and the knife is drawn between the skin and meat.

The simplest and most inexpensive automated tool for skinning of fillet with or without scales has been in use since 1992, and it can be attached to the processing table. This tool consists of an oscillating knife powered with a small electric motor and a system of compression springs operated with a foot pedal. Water is not needed to operate this device. One end of the fillet is placed in a slit between the knife and compression element and the tip grasped manually in a wrench which allows the skin to be pulled off the meat from under the oscillating knife. Various freshwater and marine fish species can be processed in this machine, including larger fish. Its use is recommended for small processing plants, fish markets, fishmongers, supermarkets, restaurants and catering sectors. Compared with manual operations, this machine facilitates and speeds up skinning. Some devices are small and can be placed directly on the processing table; running water and electricity are necessary for their operation. Efficiency varies depending upon the fish species. The price of these devices varies; some are quite expensive and their use is profitable only when a certain level of production is maintained. Depending on fillet size and type of machine, 20 to over 40 fillets/minute can be skinned; faster machines require a conveyor to move the fillets. Skinning machines (see Figure 3.22) are produced in many countries.

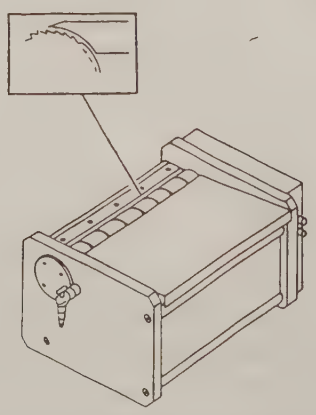


Figure 3.22 Skinning machine with stationary knife

3.3.12 Meat-bone separation

In recent years a new trend has emerged to effectively process raw fish products which resulted in production of minced meat separated from inedible parts, such as bones, skin and scales. During filleting a considerable amount of meat is usually left along the ribs and backbone (30-50%). The carcasses are a source of minced meat. Minced meat is also produced from less valuable fish species after deheading, their body cavities carefully cleaned and kidney tissue removed. Meat is separated from the bones, skin and scales, in automated devices called separators. In the separator shown in Figure 3.23, meat is squeezed through holes into the cylinder under pressure applied by a conveyor belt partially encircling the cylinder (about 25% of the cylinder's perimeter). The cylinder rotates slightly faster than the conveyor. The openings in the cylinder are usually 3-7 mm in diameter. For processing of freshwater fish, the holes are 4 and 5 mm in diameter. The smaller the holes, the stronger the grinding action. Pressure applied by the conveyor to the cylinder can be regulated depending on the type and size of the raw product and on the hole diameter.

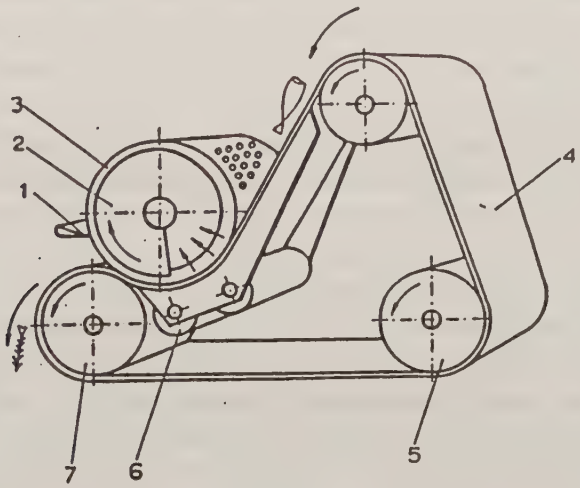


Figure 3.23 Diagram of meat separator:
1 - scraper, 2 - screw type meat remover,
3 - perforated drum, 4 - rubber band,
5 - band tension roller, 6 - pressing roller,
7 - transmission roller

The use of separators for processing such freshwater species as perch, bream and tench, offers a new perspective on production of novelty products which could gain customer approval and be successfully marketed. Minced meat can be either frozen in cardboard or foil containers, or used immediately to produce fishburgers, fish sticks, canned fish, vegetable mixes and fish dumplings. The technological efficiency attained during the production of ground meat from bream not larger than 1 kg, was 40% of total body weight. For example, in Poland in a small fish processing plant which employs 8 workers, 1 t of frozen ground bream meat can be produced during one shift. According to routine practice, ground meat can be stored at -25°C to -28°C for up to 6 months.

In Hungary, minced fish meat is made from freshwater species, mostly cyprinids 1-3 kg in weight. Halves (fillet with backbones) obtained mechanically, are the raw material. The minced meat is dried and later added to fish soups.

4. FRESHWATER FISH PROCESSING - EQUIPMENT AND EXAMPLES OF TECHNOLOGICAL LINES

In small freshwater fish processing plants only limited preservation methods are used as compared with marine fish processing establishments. The main methods of freshwater fish processing and technological examples are discussed below.

4.1 Chilling and Storage of Chilled Products

Decreasing the temperature of the fish to about 0°C slows down the microbiological, chemical and biochemical decomposition processes and extends fish stability. Thus when the raw material is cooled quickly, just after capture, and kept at low temperature during transport, processing and distribution, it meets the basic processing requirements. Its usefulness is extended and at the same time fish quality is maintained.

In freshwater fish processing the raw material, and semi-products and final products are almost exclusively ice-cooled. The heat exchange process between fish and ice is complex as it takes place between the fish surface and the ice, between the surface of fish and the melting ice water, and also between the fish and the cool air in spaces between the pieces of ice. Overall, it is a dynamic process, changing minute by minute. Water from the melting ice plays the most important role as it causes a typical convective exchange of heat. But the direct exchange of heat between ice and fish is also important, and thus the ice granulation is very important for the whole process.

In modern fish processing plants, especially the small ones, flake ice generators dominate as flake ice ensures major contact surface with fish and its production cost is low. Flake ice production consists in freezing a thin layer of water on the cooled surface of a cylindric evaporator and then scraping off the ice with a knife.

Modern ice generators generally comprise a vertical cylindric evaporator. Ice is formed on the outer, inner, or on both the surfaces of evaporators (Figure 4.1).

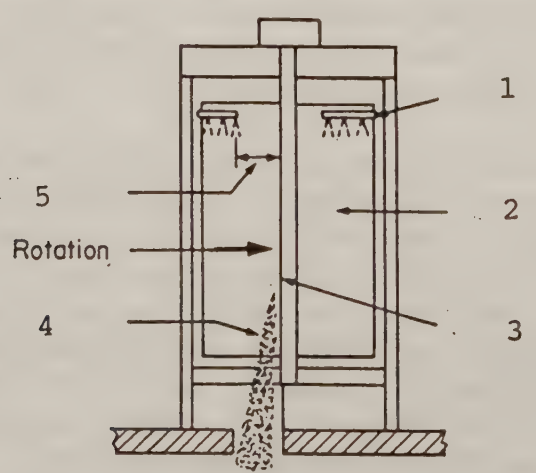


Figure 4.1 Flake ice maker (Graham *et al.* 1993):
1 - water spray, 2 - ice freezing drum,
3 - ice breaking device, 4 - ice to store,
5 - subcooling zone

Ice production is a continuous process and ice is collected in an insulated container. When the container is full the mechanism stops functioning. Capacities of flake ice generators vary from 100 kg/24 h to 60 t/24 hours. However, due to the high cost of equipment, fish producer should rather consider purchasing flake ice from the nearest cold store plant.

When the producer decides for organizational reasons (e.g., production unevenly distributed in time) to buy an ice generator it is advisable to buy two small capacity generators instead of one of a greater capacity.

The effectiveness of temperature exchange depends on the thickness of the layers of fish and the distribution of ice. For example, an 80 mm layer of fish requires two hours to decrease the temperature from 10°C to 17°C when exposed to double-sided cooling, and about 24 hours when exposed to one-sided cooling.

To evaluate optimal conditions for fast cooling of fish, many parameters (degree of ice granulation, temperature of the fish and the environment), which influence the activity of the process, should be known.

Greater amounts of ice do not shorten the process. It was ascertained that use of 25% ice in relation to the amount of fish causes temperature to drop to 5°C after 3.3 hours, for 50% ice - cooling down to 1°C takes 6 hours, but for 75% ice - 2.25 hours.

Standards for use of ice should be set individually for different types of fish and fish products, different conditions, seasons, etc. The ambient temperature does not affect the cooling rate of the fish, but considerably affects the amount of ice necessary to maintain a low temperature. It is difficult to determine the exact amount of ice needed to keep the fish temperature at about 0°C. In short-distance transportation (up to 24 hours) during the cold season (up to 10°C) 1 kg of flake ice is sufficient to cool 8 kg of fish. When ambient temperature exceeds 10°C, 1 kg of flake ice suffices for 4 kg of fish.

Proper handling of freshwater fish as raw material and its products ensures continuous cooling with ice and maintenance of temperature. All processing phases should be as short as possible and if for any reason a surplus of raw material occurs this should be sent to the cold stores.

Raw materials and products should be transported so as to ensure the maintenance of temperature close to 0°C; this involves both the most simple isothermal vehicles and mechanically-cooled containers. Fish and fish products should reach the buyer without delay. In practice, in freshwater fish processing the wholesale storage phase is omitted due to the small scale of this kind of production. Products are delivered direct to shops where they should be placed in cold stores and if necessary ice should be added. Good trade practice indicates that retailers should only keep a one-day stock of cooled fish or fish products such as fillets, deheaded and gutted fish.

The following diagrams show the flow of technological processes for chilled products (Figures 4.2, 4.3, 4.4).

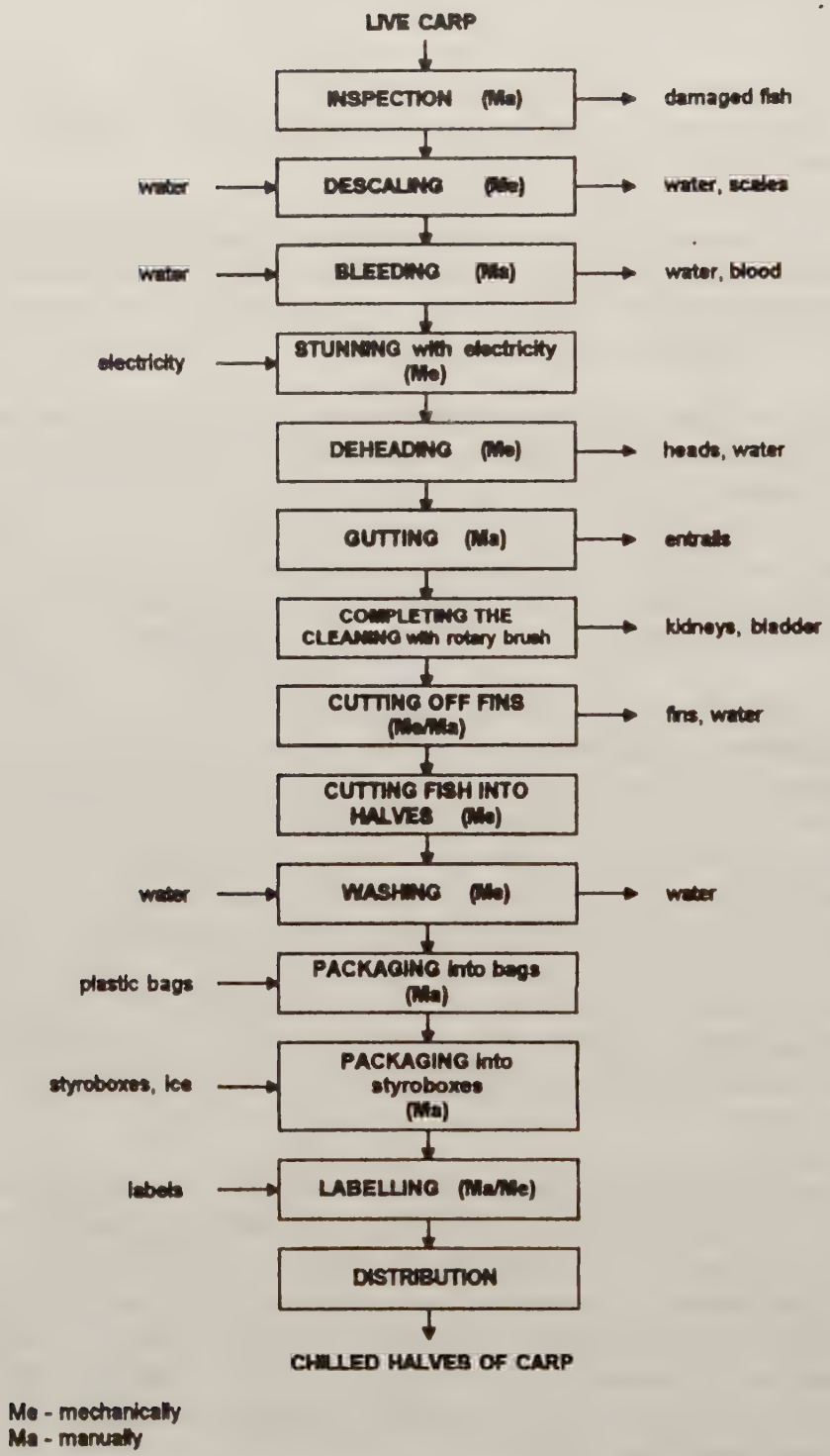
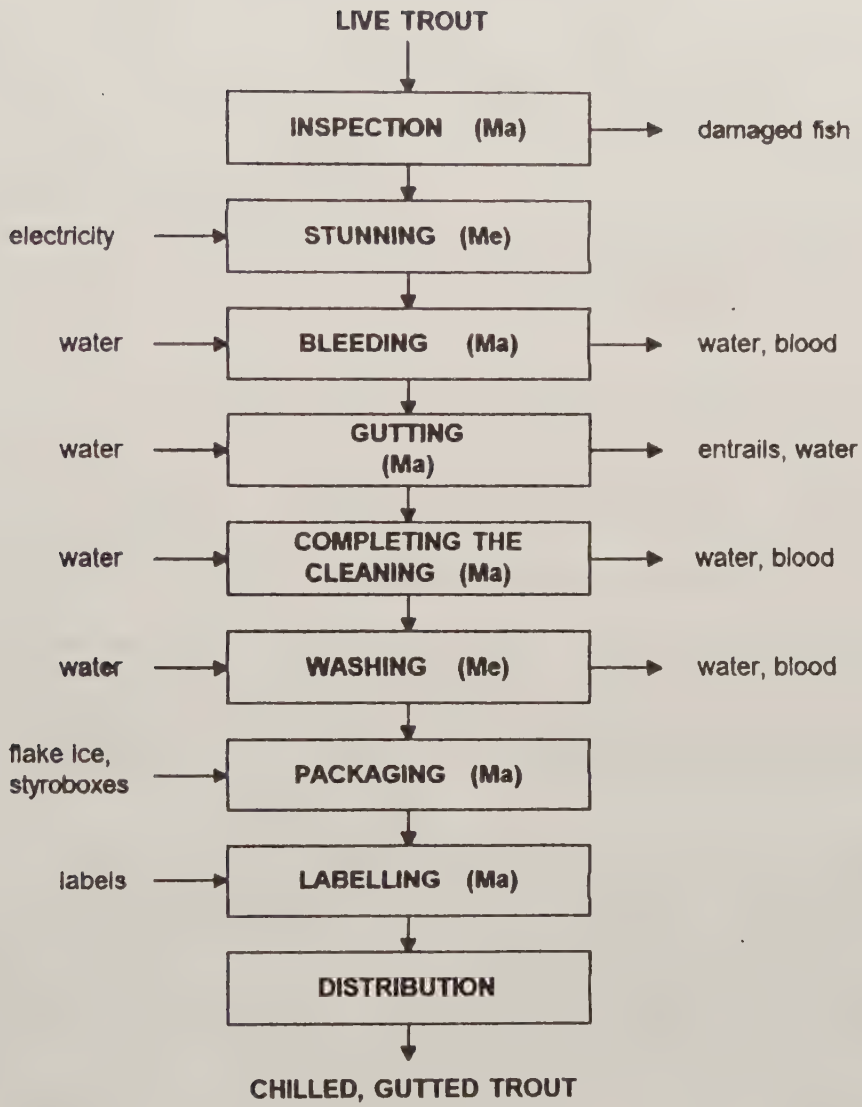


Figure 4.2 Production of chilled halves of carp (technology used in Czech Republic)



Me - mechanically
Ma - manually

Figure 4.3 Production of chilled, gutted trout

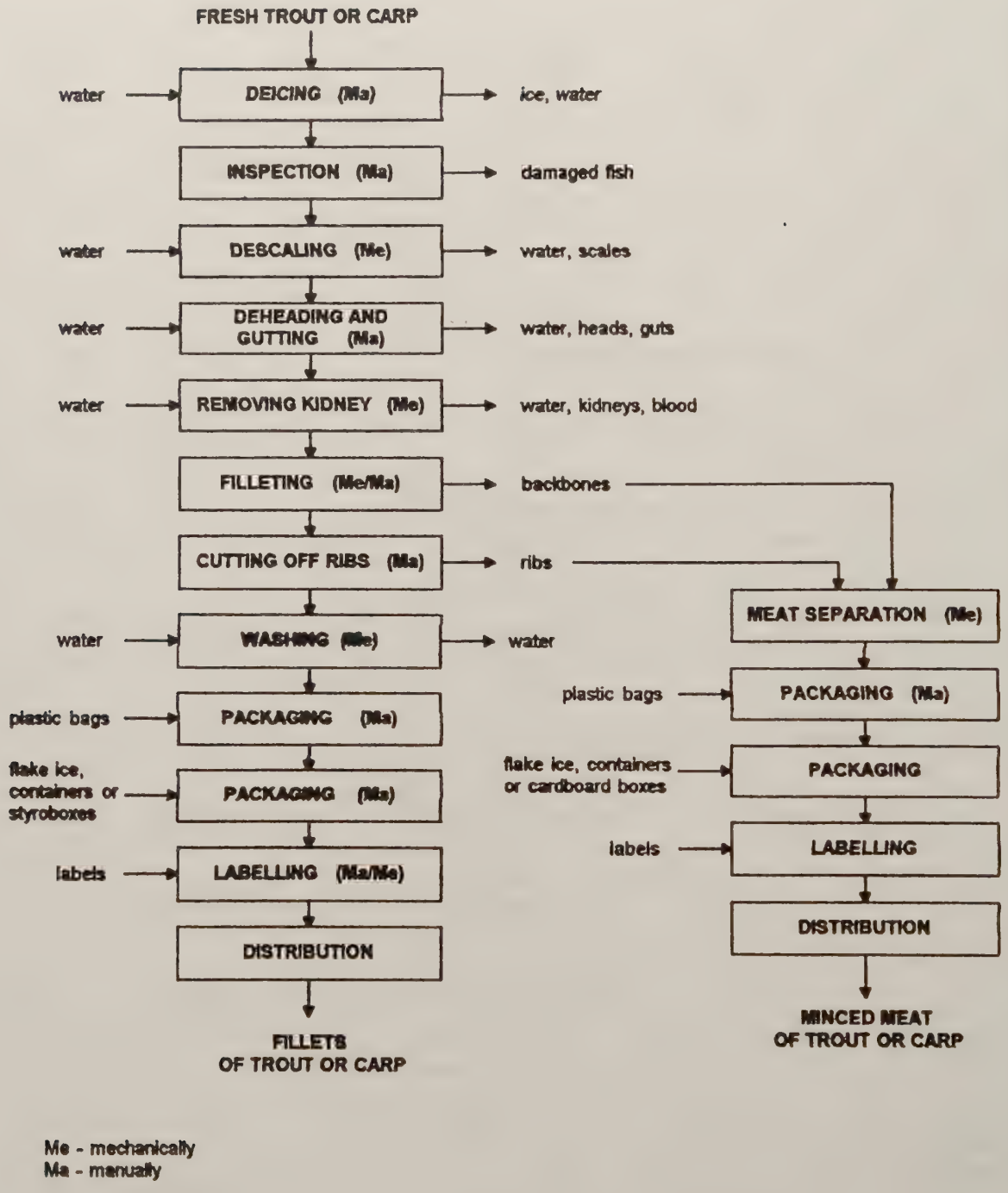


Figure 4.4 Production of chilled fillets of trout and carp (technology used in Poland)

4.2 Freezing and Refrigerated Storage

Even when the most effective chilling methods and further chilled storage of raw fish and fish products are applied, shelf life is limited. Freezing is needed to extend shelf life for long periods. This can be achieved by changing two parameters: first, a considerable decrease in temperature, and second, by freezing the water in the fish tissue. The second is of particular importance because water in the fish tissue acts as a solvent for many organic and mineral compounds which are a suitable environment for the growth of micro-organisms and also because they influence the biochemical processes. At the same time, the frozen water in the tissue causes changes in muscle tissue as a result of damage of cell structure during the formation of ice crystals. Further, the denaturation of proteins takes place during this process. An increased drain of tissue fluids, fat oxidation and dehydration are the effects of denaturation which are visible after the defrosting process. During the freezing process the majority of micro-organisms is inactivated and only psychrotrophic bacteria can develop in such conditions and to a limited degree. A temperature of about -10°C is a limit for growth of such micro-organisms. Some moulds and yeasts multiply very slowly at -15 to -18°C.

Fish should be frozen rapidly in order to produce the highest quality frozen products. Quick freezing implies a fast change from cryoscopic temperature to -5°C. During this period (about 2 hours) the main changes take place in fish tissue. A faster freezing process is linked to the formation of smaller ice crystals which damage the cellular membranes to a lesser degree, especially if freezing takes place before *rigor mortis* sets in.

The size of the ice crystals depends on the duration and temperature at which the fish was chilled/stored prior to freezing. The longer the time and the higher the temperature the bigger the crystals. Changes of proteins and oxidization of lipids in muscle tissue are the results of slow freezing process and unsuitable conditions (time, temperature) of fish storage before freezing. These affect the quality of the final product.

In small fish processing plants there are usually two kinds of freezing equipment: chamber freezers and contact-plate freezers. The simplest is the chamber freezer-batch air blast freezer which consists of a battery of evaporators, a ventilator for air circulation and a rack for trays with fish products or for unpacked raw material. Versatility is the main advantage of such freezers as they make it possible to freeze different kinds of products, for example, regular shape blocks of fish/fillets and individual fish/fillets on the wire nets.

For that reason such freezers can be used in small plants; but high energy consumption and their large size are the main disadvantage. Contact freezers are far less common in fish processing plants with low daily production. Their operation consists in placing the fish for freezing between two plates which are cooled mechanically. This device is installed exclusively for freezing fish which is in regular blocks. In these freezers, good contact between the plates and the fish is essential to ensure rapid removal of heat from the product. Many kinds of such freezers are available including those with limited capacity, e.g., 1 500 kg/24 h, and requiring little space, about 1.2 m^2.

Even properly frozen fish has limited storage life. Low temperatures inhibit processes of microbiological decomposition but do not protect against fat oxidation and loss

of water. The stability of frozen fish depends on the initial quality of the raw material, the rancidity, the drying process and the storage temperature.

Glazing is the simplest and cheapest method which effectively prevents water loss of from fish tissue and prevents rancidity. Glazing consists of forming a very thin adherent layer of ice on the fish's surface. This method is used especially for freezing of whole fish or in fish/fillet blocks. Individual portions of fish or individual fillets are packed in plastic material characterized by low permeability of water vapour and oxygen. This prevents rancidity and loss of water.

The storage temperature of frozen products is the next factor which influences the quality and stability of frozen products. Table 4.1 shows the practical storage life of fish products in relation to temperature. Unfortunately, industrial practice shows that the basic principles of freezing process are often not complied with, especially in small and poorly equipped establishments. Fish is frequently frozen in store chambers, home freezers, etc. The capacity of such chambers is limited, temperature is not stable and generally lower than required. Further, no temperature recording is made. Low quality of products results from such practice, particularly texture and flavour; fish becomes dry and very often discoloured.

Table 4.1 Practical storage life (PSL) of fish products in relation to storage temperature

Fish product	Storage life in months		
	-18 °C	-24 °C	-30 °C
Fat fish glazed	5	9	> 12
Lean fish fillets	9	12	24

4.3. Smoking of Freshwater Fish

Smoked freshwater fish such as eel or trout, and less often carp, are the most popular fish products. Saturation of raw material with wood smoking is the main principle of the smoking process. During this process, some water is removed from the tissue and changes of proteins occur. The smoked fish is then ready for consumption without further culinary treatment.

There are two methods of fish smoking: hot and cold, which give very different products. The difference lies in stability and sensory properties which in turn depend on a degree of fish dryness and saturation with smoke components.

Smoke is produced by a not complete burning of some type of wood and is a mixture of more than a hundred chemical components. The chemical composition of smoke depends on the type of wood and traditionally deciduous tree wood is used.

During the smoking process sensory features such as colour and flavour undergo changes. The colour of properly smoked fish depends on the quantity and composition of

the smoke components absorbed through the fish surface; the higher the smoke density the darker the colour of the fish. Smoke density and humidity inside the smokehouse influence smoked fish characteristics. Flavour is the most typical feature of smoked products. It is generally considered that phenol compounds and other components soluble in water are the most important criteria in creating flavour in smoked products.

The presence of antioxidants in smoke renders smoked products resistant to rancidity. Hot-smoking reduces microbiological growth thanks to high temperature (close to 80°C in tissue) and the antiseptic components of smoke. Generally, after hot-smoking fish products contain only meso- and thermophilous micro-organisms, resulting from heating the product and not the antiseptic action of smoke components and salt content. Cold-smoking enables preservation of the product by smoke components. Their concentration in the product is higher than in hot-smoked fish and the product is drier. The vegetative forms of micro-organisms are the most sensitive to smoke treatment but spores of moulds are relatively resistant. For that reason, smoked products often grow with mould - the main disadvantage.

The hot-smoking process includes the preliminary processing of raw material, brining, drying to a certain loss of water content, the actual smoking process and thermal treatment at temperatures above 30°C, usually 70-80°C (Figure 4.5, 4.6, 4.7).

The cold-smoking process involves no thermal treatment and the entire process is carried out at temperatures below 30°C (Figure 4.8).

During hot-smoking, brining is carried out to ensure penetration of about 2% of salt into the fish tissue; the salt gives the desired taste to the product. During cold-smoking, salt is required for the conditioning process which favours the action of the enzymes. However, the brining process can be a source of microbiological reinfection. It was shown that multiple use of brine, 20% salt content, may produce a source of many micro-organisms including spores of *Clostridium botulinum*. The brine thus needs to be changed frequently.

Drying is carried out in order to reduce the water content in fish tissue to a level which ensures product stability and texture. Usually 25-30% weight loss takes place during hot-smoking and 40-45% during cold-smoking.

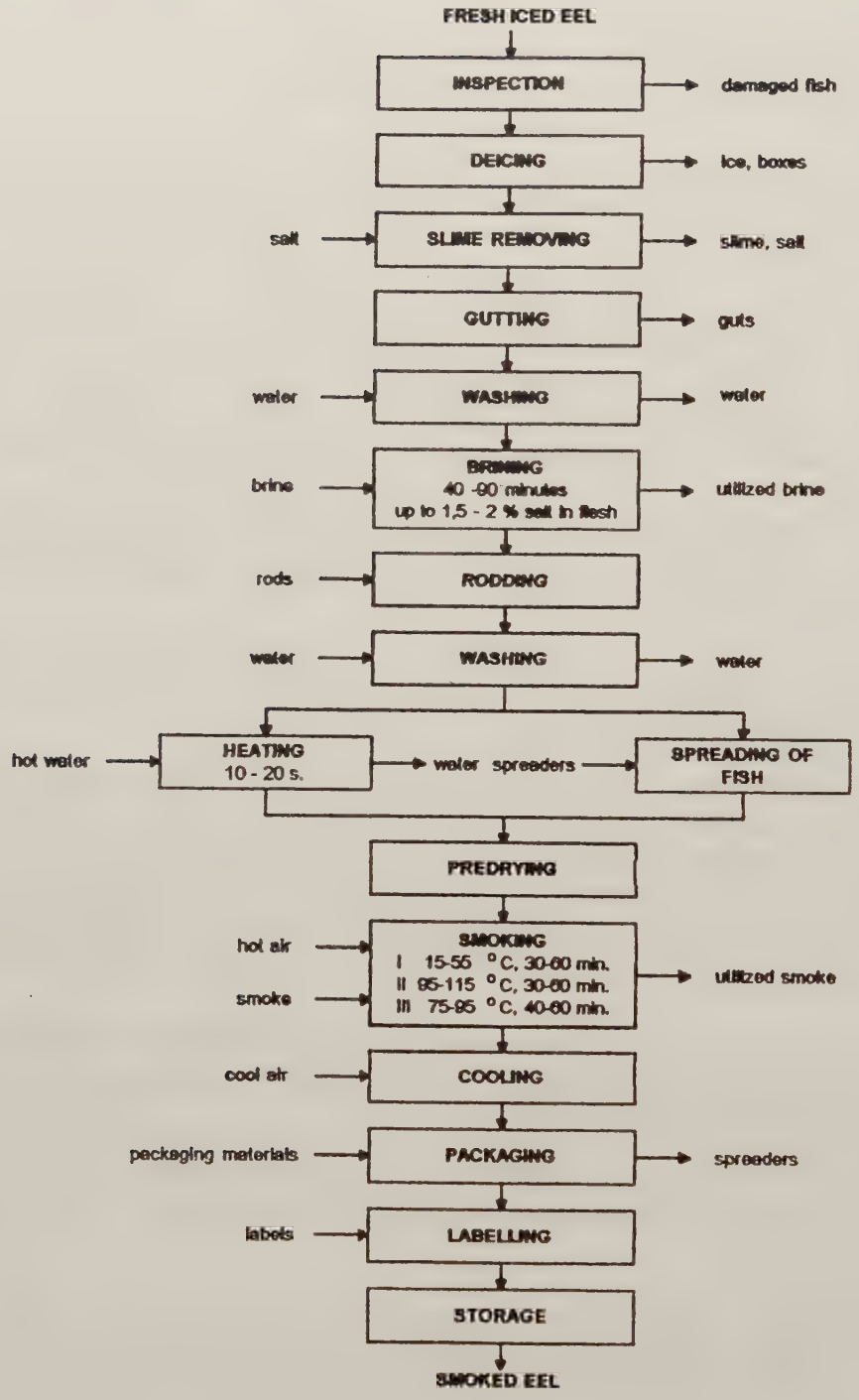


Figure 4.5 Flow diagram of hot smoking of eel:
I - Preliminary drying
II - Thermal treatment
III - Smoking

Process yield: 140-170 kg of fish as raw material, 100 kg of final product

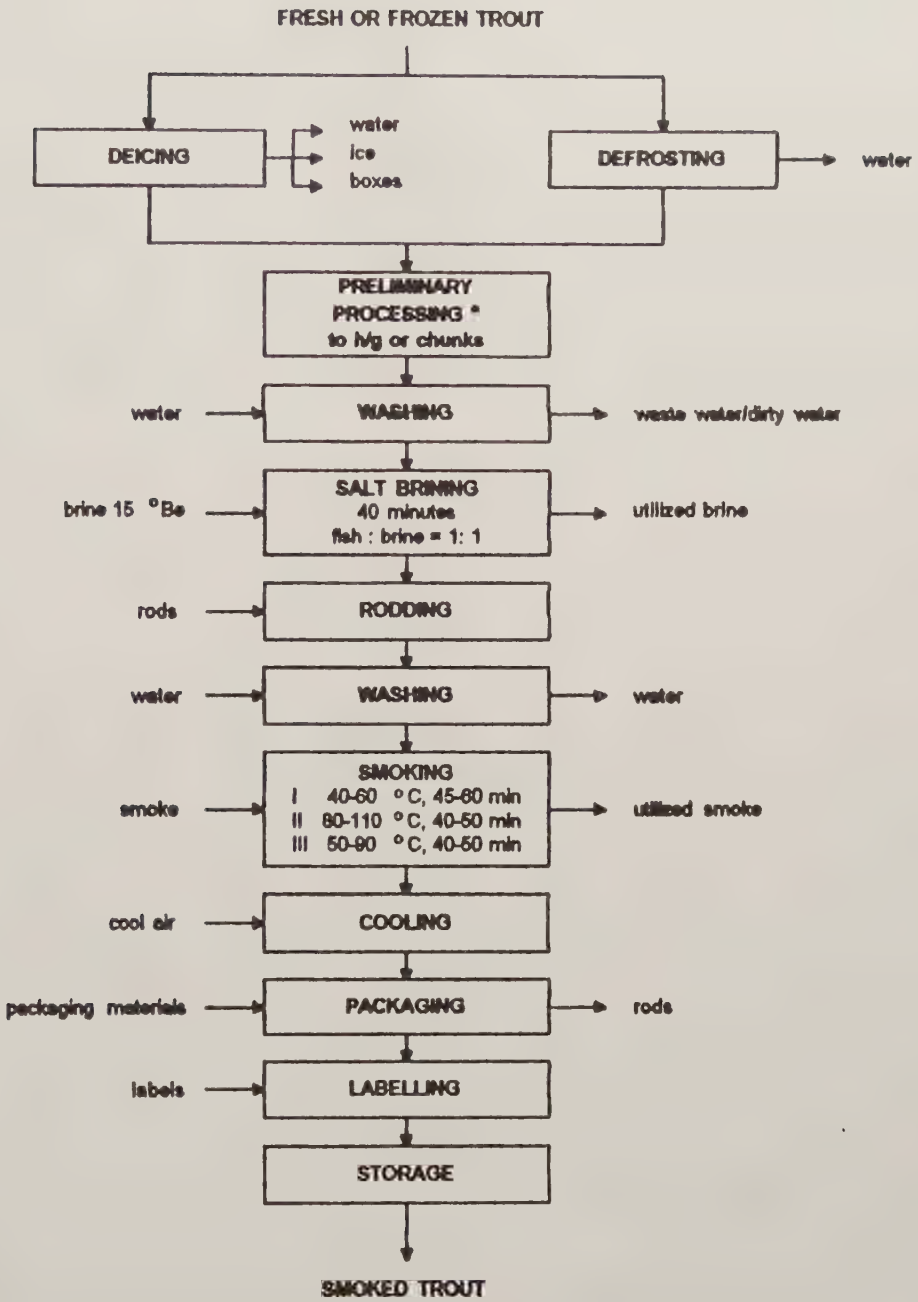


Figure 4.6 Flow diagram of hot smoking of trout:
I - Preliminary drying
II - Thermal treatment
III - Smoking

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* See section 3.3, preliminary processing covers: deheading, cutting, gutting, removing of kidney, cutting off fins; big fish can be cut into pieces 50-70 mm thick

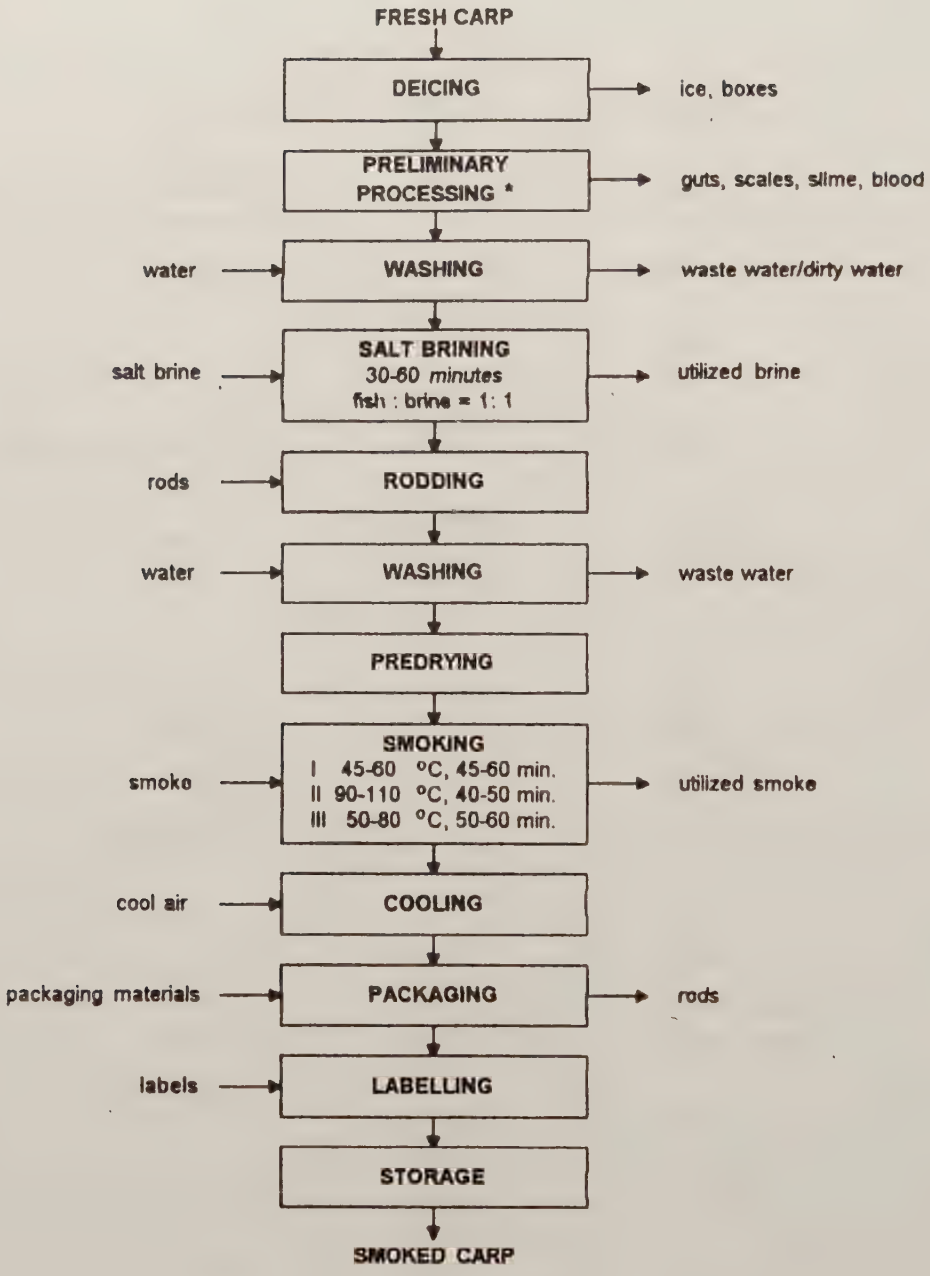

Figure 4.7 Flow diagram of hot smoking of carp:
I - Preliminary drying
II - Thermal treatment
III - Smoking

Process yield: 155-170 kg of raw material, 100 kg of final product

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* See section 3.3, preliminary processing covers: scaling, cutting, gutting, removing of kidney, blood and slime from the surface of fish

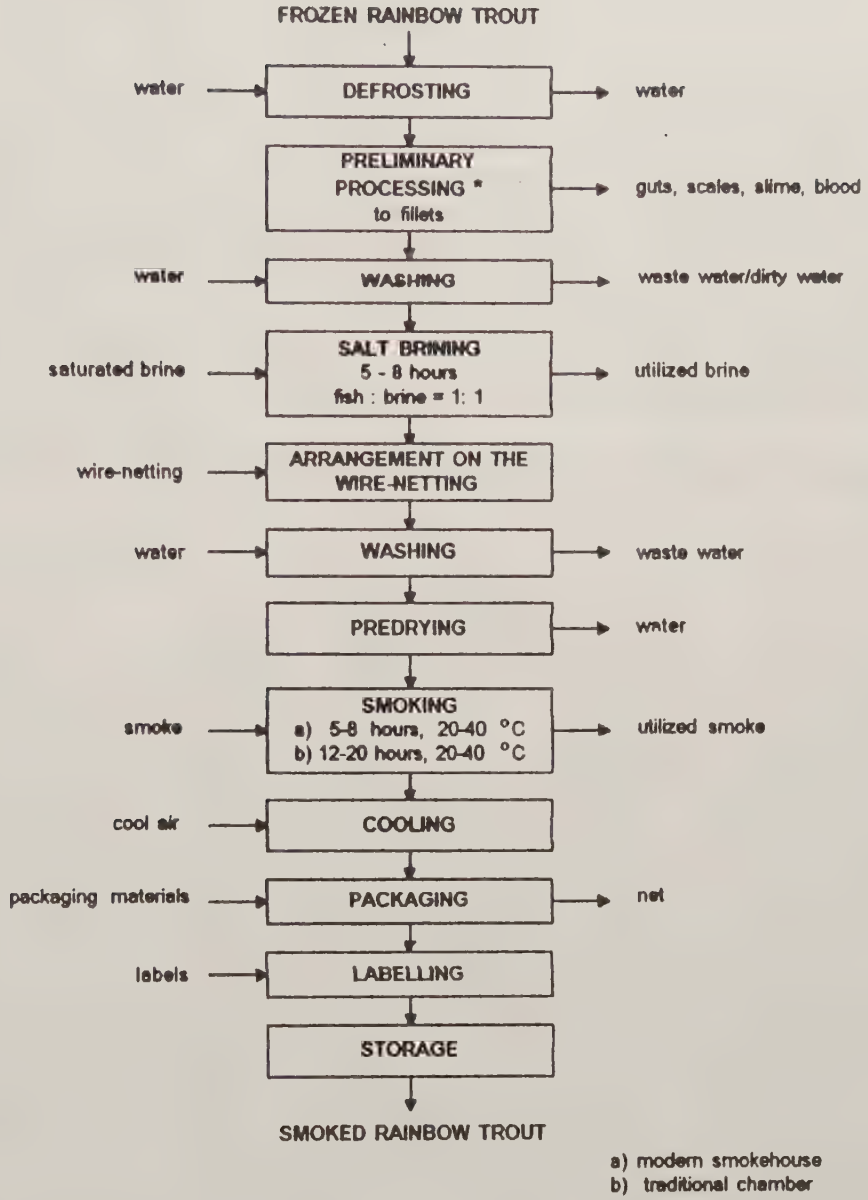

Figure 4.8 Flow diagram of cold smoking of rainbow trout fillets:
I - Preliminary drying
II - Thermal treatment
III - Smoking

Process yield: 290-310 kg of raw material, 100 kg of final product

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* See section 3.3, preliminary processing covers: scaling, removing slime from skin, filleting, removing blood, clotted blood and peritoneal traces

During hot-smoking thermal treatment should be continued until the temperature inside the thickest part of the fish reaches about 70°C. This ensures the denaturation of proteins and destruction of micro-organisms to a high degree. In some countries, e.g., the USA, fish originating from the Great Lakes could be infested with *C. botulinum*. Thus fish with minimum 3.5% salt content should be heated up to 82.2°C and thermal treatment continued for about half an hour. That process should be followed by very rapid cooling and storage at temperature below 4°C or preferably freezing. Thermal treatment should be conducted at humidity lower than 70% because of bacteriological effect. Thermal treatment in the modern smoking house (Figure 4.9), very often equipped with an automatic control stem and adjustment of processing parameters, like air and smoke, can be programmed to maintain optimum temperature. Traditional methods of smoking do not ensure the same results but the traditional process, carried out in smoking chambers, is much cheaper. Wood is a source of smoke and energy necessary for this process. The effectiveness of traditional method depends on the experience of the operator.

Packaging materials and packaging methods of smoked products are described in section 5.

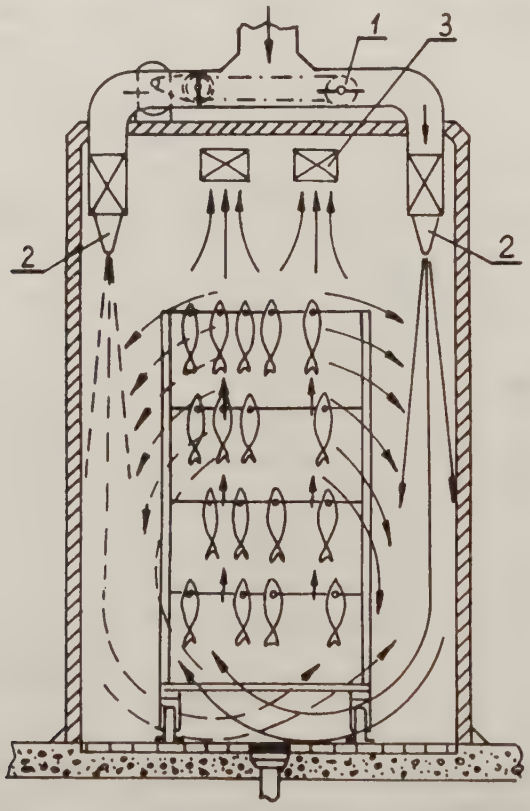

Figure 4.9 Modern smoking chamber:
1 - valve, 2 - smoke inlet, 3 - smoke outlet

4.4 Production of Fish Silage from Offal

During fish processing, a large quantity of offal is produced and its proper utilization poses a problem, particularly for smaller processing plants. Fishmeal production is not profitable because of a low supply of the raw material, and thus production of a liquid form of this fish product is the only simple solution.

Production of fish hydrolysate (silage) to be used as feed is the cheapest way of utilizing offal. Considering the capital needed and the operating costs for fishmeal and hydrolysate production (cost ratio 4:1), production of the liquid form of this by-product is very profitable and it can be done by small plants. It is a simple technological process, but several rules must be observed to obtain a satisfactory final product.

The raw material, the, offal, must be fresh; decomposing offal should not be processed. The main phases of offal processing are: grinding of offal or whole fish, acidifying of the pulp and liquefying it which results from a self-digestion (autolysis) process. Adequate grinding is a basic operation of the process.

The following preservatives are used to produce pyrosilage:

- sodium pyrosulphite ($Na_2S_2O_5$), 1% for fatty and medium fatty offal, and 1.3% for lean product,
- sulphuric or hydrochloric acid, both at 1% concentration in the mix

The measured pH should always be the final indicator of a proper level of acidification and should range from 3.5 to 4.5. The pH should never exceed 4.5.

The basic requirement of the process is to obtain homogeneity of the mix consisting of the fish, inorganic acid and sodium pyrosulphite. Homogeneity can be achieved by using slowly revolving mixers or other methods (turbulent mixing causes aeration of the mix and consequently oxidation of fatty acids). When mixing is too gentle, pockets of mix occur which do not contain preservatives, and decomposition of the product by the bacteria may begin. Each day the end-product is pumped into the retaining tank(s). These tanks should be equipped with mixers or recirculating systems powered by pumps. The tanks should be located under a roof to avoid solar radiation. The silage can be stored for up to 6 months if it is stirred periodically and kept at about 15-20 °C. In small freshwater fish processing plants where the volume of offal and fish not used for consumption is low (i.e., 1-2 t/shift), the production of fish hydrolysate is simplified (Figure 4.10). The processing equipment consists of a grinder (sieve openings 6-10 mm in diameter, processing capacity *circa* 400 kg/hour), dispenser with a worm-wheel unloading conveyor, rotating mixer made of suitable materials with a 150-l volume drum, and 120-l plastic barrels.

This equipment (Figure 4.10) is manned by an operator who can produce 2 t of liquid feed per shift.

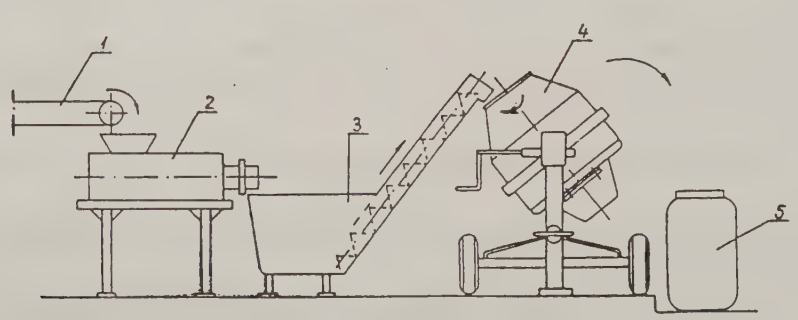

Figure 4.10 Simplified layout of silage production:
1 - feeder, 2 - grinder, 3 - tank with elevator,
4 - mixer, 5 - plastic barrel

A production cycle consists of the following stages:

- grinding of the raw product in a grinder
- loading of *circa* 100 l of ground product from the dispenser into the mixer drum, and adding 1.6-2.0 l of sulphuric acid at density 1.28-1.3
- mixing for about 10 minutes and adding a solution of sodium pyrosulphite (1 kg of pyrosulphite dissolved in 3-4 l of water)
- additional mixing for 5-7 minutes and pouring of the product from the mixer drum straight into the 120 l barrels

An approximate chemical composition of fish silage is:

- protein - about 15%
- fat - 6-14% (depending on raw material)
- ash - 2.4%
- micro-elements and vitamins

Different forms of fish hydrolysate are used for feeding pigs, poultry, fur animals and fish. Hydrolysates contain very valuable, easily assimilated proteins and fatty acids, unaltered vitamins, micro-elements and digestive enzymes. For pig and poultry feed, fish hydrolysates can be substituted for fish meal, meat and bone meal, and powdered blood. Experiments showed a 10-20% increase in weight and a lower feed use per weight gained by an animal. It was determined that 1 kg of hydrolysate equals 0.3 kg of fish meal, and its use reduces the need for feed by 0.66 kg per 1 kg of weight gained. Polish scientists reported 0.7 kg/day of weight gained when bacon-type pigs were fed fish hydrolysates.

According to Danish researchers, no more than 15% of the total feed given to pigs should consist of fish hydrolysates, and these should be detracted from the diet several weeks before slaughter. The Polish and Danish experiments confirmed the positive results of feeding poultry with fish hydrolysates instead of fish meal (chickens were fed hydrolysates in amounts equal to 50% of the daily protein requirement). Substitution of dry animal and fish meal with hydrolysates gave very good production results:

- use of feed per 1 kg of weight gained equal to 2.54 kg
- mean body weight of an 8-week old chicken was 1.20 kg
- slaughter efficiency higher by 23%
- costs of the components used in the feed lowered by 20%
- content of additional animal feed lowered by two-thirds, that is, by 110 kg/1 t of combined feed, fish and meat meal, and powdered milk

5. PACKAGING USED IN FRESHWATER FISH PROCESSING

5.1 The Role of Packaging

The previous section discussed the processing methods most often used by small freshwater fish processing plants. Quality assurance is essential in each technological process, and suitable packaging materials and methods are of great importance. If these requirements are not met all efforts made during processing could be of little avail, which could lead to serious economic losses.

Packaging should protect the product from contamination and prevent it from spoilage, and at the same time it should:

- extend shelf life of a product
- facilitate distribution and display
- give the product greater consumer appeal
- facilitate the display of information on the product

The quality of freshwater fish which is delivered to the consumer or the processing plant as live fish greatly depends on correct handling during transport and, when processed, on suitable packaging. For short distances, the live fish can be transported in insulated containers with lids, capacity varying from 300 to 1 000 kg of fish. Fish can also be transported in normal lorries, but for long distances the water in the containers must be aerated and cooled by portable devices.

In order to maintain good quality of fresh fish during transportation, fish boxes made of suitable materials should be used. When purchasing fish boxes the six following requirements should be remembered; they should:

- be of a suitable size for the range of fish to be handled or the product to be put into them
- be of a convenient size for manual handling or lifting by mechanical equipment
- be stackable such that the weight of the containers on top rests on the containers underneath and not on the fish
- be constructed of impervious non-staining materials
- be easy to clean
- provide drainage for melted ice

Fish boxes are usually made of high-density polyethylene. Although this offers many advantages, such as duration, lightness, ease of cleaning, there are also disadvantages, e.g.,

high price and the fact that they are not returnable. That is why disposable fish boxes of about 25 kg capacity (fish and ice) are more often used: these include fibreboard cartons, waxed and waterproof boxes. In the case of transport by lorries with no cooling system, insulated cartons, e.g., boards made of moulded polyestyrene should be preferred. The latter is commonly used for delivery of chilled and frozen fish and fish products to wholesale and retail outlets. In the case of fillets, each layer of fillets should be packed thin and separated from the ice with a plastic foil.

Styropor boxes are normally sold with lids, which fit very closely and can be with or without drainage holes. In a typical range, wall thickness varies with box size; e.g., a 6 kg capacity box has a 15 mm thick wall, a 10 kg box a 19 mm wall, a 25 kg box a 25 mm wall. The main disadvantage of moulded polyestyrene fish boxes is their lack of strength. They are easily damaged or broken by rough handling. This limits their size and use.

Polyestyrene is difficult to clean. Polyestyrene boxes are difficult to re-use, and are usually non-returnable. They may cause disposal problems due to their bulk.

The packaging industry improves its products by using new materials with better insulating properties or by introducing new leakproof designs. The new containers are often lighter and less bulky. For example, the Therma Gard packing system consists of a metallized plastic bag (which reflects practically all radiant heat). This is then wrapped in a waterproof and leakproof carton. The metallized bag, together with a bubble-pack wrapper, provides a double-pack insulation. The Therma Gard bag can be sealed airtight and thus be used for carrying live fish. The Stratech aluminized boxes have a wall thickness of only 5mm and it is claimed that these boxes have similar insulating characteristics as polystyrene boxes with 30 mm wall thickness.

The future use of expendable packages is becoming questionable as there is a growing discussion, for example in some states of the USA, on imposing a ban on these packages.

The main drawbacks in using returnable containers are freight costs for returning empty containers. Use of "knock-down" returnable containers will reduce freight costs.

5.2 Retail Packaging for Freshwater Fish Products

The main role of packaging is described above but in respect of retail presentation it should also reduce the smell and the drip, and enable the product to be tucked into shopping baskets with other purchases. Moreover, the packaging of fish products should ensure attractive presentation among other food products without contaminating them.

Basic packaging materials include paper, cartons, sheets of metal, metal foils and many kinds of plastics. Despite the rapid growth in use of plastics, the role of paper and carton as packaging materials does not decrease.

Kraft paper or carton are often laminated with polyethylene or aluminium foil which render them waterproof. Such material is used for production of trays for packaging of fresh or frozen products. More often, trays are made of plastic materials such as polyestyrene or expanded polyestyrene. Expanded polyestyrene is frequently used but it is partly oxygen-

permeable and so those products which are sensitive to rancidity have to be additionally overwrapped or skin-packed with suitable film.

The materials mentioned above are not stable at high temperatures and hence are not suitable for trays to be used in an oven. Polyester can be used as a packing material for heating of the product in the traditional and microwave ovens, but this material cannot be used for microwave cooking.

Trays used for packing are generally overwrapped with a protective film, often with PE wrapping which shrinks. The film shrinking is achieved by use of hot air or hot water.

Stretch wrapping is often used for products which are heat-sensitive. The film is stretched over the product manually (very often in the supermarket) or by machine. Foils used as wrapping or bags for packing of trays with product must be puncture-proof, extensible and impervious to gases like oxygen.

Hundreds of different films are used in the packaging industry. These can be broadly categorized into two groups:

- basic films consisting of a single layer of film

- laminate consisting of two or more basic films glued together or bonded together by heat or by adhesives

Plastics such as polyethylene film or copolymer of ethylene and vinyl acetate are very often used for packing of frozen products. Polyethylene packs can be produced manually using pre-made bags. An impulse or bar sealer is used to seal the bags which are hand-filled.

In order to improve the barrier properties of packages laminates are used, for example polyester/polythene. Products which are particularly sensitive to oxygen are vacuum-packed. During the sealing operation, air is removed from the package. A laminate nylon/polythene is commonly used as packaging material. This type of packaging is used, for instance, for smoked trout which are arranged on a board with, for example, a coated texture. Numerous machines exist for vacuum-packing with single, double or continuous chambers. Vacuum-sealing machines can additionally be equipped with a modified atmosphere packing system (MAP). Immediately on removing the air from the package a mixture of gases is pumped in. Usually this mixture consists of 30% nitrogen, 40% carbon dioxide, and 30% oxygen. In the case of fat fish the oxygen is replaced by nitrogen. This method is increasingly used for packing fresh fish. The MAP products have to be stored at the temperatures lower than 3°C because of *C. botulinum* hazard. MAP packages consist of two kinds of foil. The bottom film is foil-rigid or semi-rigid. This foil is formed by, for example, extrusion and the resultant tray is moved to the packing section. Because of product drip it is placed on an absorbing board. The top web is drawn over the filled trays and sealed round the edges. The pack may be evacuated or gas-flushed before sealing.

Vacuum-skin packaging is becoming more common for packing smoked fish. In this process the wrapper is heated and wrapped over the product, the film moulding completely to the product shape and sealing the product completely, forming an extra skin.

5.3 Labelling Requirements for Freshwater Fish Products

Lack of detailed standards and existence of only limited regulations concerning wholesomeness and sanitary conditions for production and trade of food products characterize the market economy. Here, the problem of labelling is of a particular importance. Regulations in this regard are very detailed and are aimed at protecting the health of the consumer and providing the best information. These requirements enable the consumer to decide which products to buy. A label placed on the product should inform the consumer about the raw material used, method of preparation and form of consumption, shelf life, etc.

Product labelling is of prime concern in the European Union. Directive 79/112/EEC of 18 December 1978 was revised several times, and in 1990 there came into force a new Directive 90/496/EEC which concerned labelling and providing information on nutritive and energetic values (kcal or kJ/100 g or 100 ml), the amount of basic ingredients and nutritive compounds such as: proteins, carbohydrates, fat, fibre, sodium and vitamin content (EEC, 1979). These requirements were supplemented in Directive 89/396/EEC recommending the labelling of batches of product which would make it easier to withdraw the batch from commodity turnover in the case of health hazard.

Taking into account the necessity to ensure complete information on the product to facilitate the selection of a healthy and economic diet, the US Food and Drug Administration (FDA) recently proposed a voluntary Nutritive Labelling Programme which covers, *inter alia*, a proposal for placing on the product for example information concerning the percentage of recommended daily intake of protein, vitamin A and C, iron, calcium, etc.

6. ESTABLISHMENTS AND PRODUCTION DEMANDS FOR FRESHWATER FISH PROCESSING

Many publications exist on the subject of establishments and production demands for freshwater fish processing. There are also specialized authorities which deal with food/fish processing plant design. However, many small establishments emerge as a result of restructuring or modernization of already existing buildings; e.g., the authors have converted the building where sheep-farming was carried out into a trout processing plant. The owner of the small processing plant is also often its designer because of lack of money to pay a professional consultant. For these reasons, remarks and guidance on plant design are set out below (Shapton and Shapton 1991, Hayes 1985, EEC 1991).

6.1 Plant Location, Buildings and Layout

Before deciding plant location different factors should be analysed. The most important is the plot which should be of adequate size for both present needs and future development. The plant should be close to public transport such as rail or road. Access to electricity, water, and steam is essential. Waste disposal should be considered when planning the plant location. The owner should coordinate all the works with local competent

authorities in order to avoid problems in the future. The choice of plant location should also take into account the neighbouring surroundings: for example, location near to a waste dump could lead to microbiological contamination caused by birds.

A well designed building should comprise sufficient space for work to be conducted out under adequate hygienic conditions, an area for machinery, equipment and storage, separation of operations that might contaminate food, adequate natural or artificial lighting, ventilation, protection against pests.

There are many technical regulations concerning construction of buildings and processing halls; e.g., outside walls, windows and doors should be constructed such that they are water-, insect- and rodent-proof. The inside walls of the building should be painted white or other light colour and their surface should be smooth, fall-safe, corrosion-proof and easy to clean.

Floors should be resistant to spillage of products, water and disinfectants. They should be slip-proof and maintain their colour. Experience shows that selection and preparation of the floor is one of the most difficult tasks facing the designer. The main problem, however, lies in appropriate general layout and arrangements of rooms which must minimize the risk of contamination of the final product.

The majority of pathogens and spoilage micro-organisms derive from the raw material. In order to avoid cross-contamination the raw material should be placed in separate cold stores. The best solution seems to be separation by walling-off the unclean area from the clean area. The unclean area is where the raw material is delivered, sorted and possibly processed, e.g., gutted. Clean areas are places of production where any contaminants added to the product could be transmitted to the product, i.e., there is no subsequent processing step that will reduce or destroy the contaminating microbes. Thus separation of these areas has to be complete and there should no movement of people or equipment from unclean to clean area (Figure 6.1).

Proper layout and designs should ensure an uninterrupted and "straight line" process flow, and should meet other requirements listed below (Shapton and Shapton, 1991):

- all functions should avoid zigzagging and backtracking
- visitors should move from unclean to clean areas
- conditioned (chilled) air and drainage should flow from clean to unclean areas
- the flow of discarded outer packing material should not cross the flow of either unwrapped ingredients or finished product
- there should be sufficient space for plant operations including processing, cleaning and maintenance; space is also required for movement of materials and pedestrians
- operations are separated as necessary. There are clear advantages in minimizing the number of interior walls since this simplifies the movement of materials and employees, simplified supervision, and reduces the area of wall that needs cleaning and maintenance

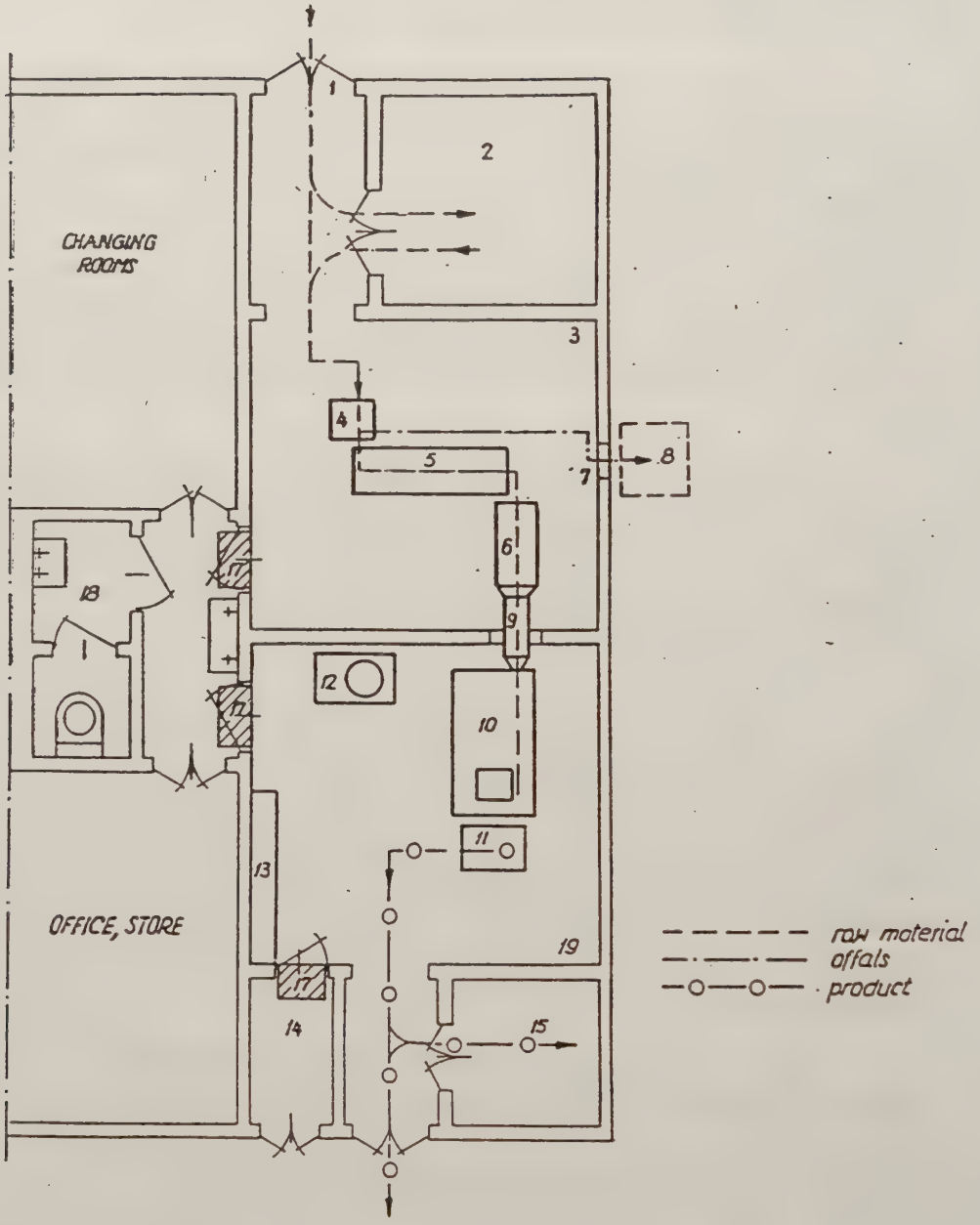

Figure 6.1 Layout of simple processing factory:

1 - entrance corridor, 2 - chilled raw material store-room,
3 - production room (unclean area), 4 - stunning of fish,
5 - table, 6 - washer, 7 - chute/transporter,
8 - container with cover, 9 - chute through the window,
10 - table with scale, 11 - trolley, 12 - ice generator,
13 - shelf for packaging, 14 - packaging store-room,
15 - chilled product store-room, 16 - exit,
17 - disinfection mat, 18 - toilet,
19 - production rooms (clean area)

The proper design and arrangement of the processing plant greatly influence food production hygiene. Council Directive 89/392/EEC of 14 June 1989 (EEC 1989) on regulations concerning machinery safety and hygiene contains the following most important requirements:

- machinery containing materials intended to come in contact with food must be designed and constructed so that these materials can be cleaned each time they are used

- all surfaces and joints must be smooth, with no ridges or crevices that could harbour organic materials

- assembly must be designed so as to minimize projections, edges and recesses; they should be constructed by welding or continuous bonding, with screws, screwheads and rivets used only where technically unavoidable

- contact surfaces must be easy to clean and disinfect, and be built with easily dismantled parts; inside surfaces must be curved so as to allow thorough cleaning

- liquid derived from foods, and cleaning, disinfecting and rinsing fluids should be easy to discharge from machinery

- machinery must be designed and constructed to prevent liquids or living creatures - primarily insects - from entering and accumulating in areas that cannot be cleaned

- machinery must be designed and constructed to avoid ancillary substances, such as lubricants, coming into contact with food

6.2 Personal Hygiene

Personal hygiene is a most important element of health quality assurance in a fish processing plant. According to Thorpe (1992) the essential requirements for personnel working in production area and stores are those mentioned below:

1. **Protective clothing, footwear and headgear** issued by the company must be worn and must be changed regularly. When considered appropriate by management, a fine hairnet must be worn in addition to the protective headgear provided. Hair clips and grips should not be worn. Visitors and contractors must comply with this regulation.

2. **Protective clothing** must not be worn off the site and must be kept in good condition. If it is in poor condition the supervisor should be informed immediately.

3. **Beards** must be kept short and trimmed, and a protective cover worn when considered appropriate by management.

4. **Nail varnish, false nails and make up** must not be worn in production areas.

5. **False eyelashes, wrist watches and jewellery** (except wedding rings or the national equivalent, and sleeper earrings) must not be worn.

6. **Hands** must be washed regularly and kept clean at all times.

7. **Personal items** must not be taken into production areas unless carried in inside overall pockets (handbags, shopping bags must be left in the locker provided).

8. **Food and drink** must not be taken into or consumed in areas other than the tea bars and the staff restaurant.

9. **Sweets and chewing gum** must not be consumed in production areas.

10. **Smoking or taking snuff** is forbidden in food production, warehouse and distribution areas where 'No Smoking' notices are displayed.

11. **Spitting** is forbidden in all areas of the site.

12. **Superficial injuries** (cuts, grazes, boils, sores and skin infections) must be reported to the medical unit or nurse via the supervisor and clearance obtained before entering production areas.

13. **Dressings** must be waterproof and contain a metal strip as approved by the medical unit.

14. **Infectious diseases** (including stomach disorders, diarrhoea, skin conditions and discharge from eyes, nose or ears) must be reported to the medical unit or nurse via the supervisor. This also applies to staff returning from travel abroad where there could be a risk of infection.

15. **All staff must report to medical unit on return from both certified and uncertified sickness.**

6.3 Cleaning and Disinfection in Processing Plant

6.3.1 Water quality in processing and cleaning

As a general rule, water used for all purposes in food production must meet drinking water standards. It is noted that a universal list of biological and physico-chemical parameters for drinking water does not exist. The WHO Guidelines for drinking water quality and the guidelines prepared by EU (WHO, 1984; EEC, 1980) are similar with regard to microbiological contamination. The same situation applies concerning state regulations and only physico-chemical requirements for drinking water differ in particular countries.

Disinfectant residues should be monitored where possible and the bacteriological quality periodically checked. Turbidity, colour, taste and odour are also easily monitored parameters. If there are local problems with chemical constituents (fluoride, iron) or

contaminants from industry or agriculture (e.g., nitrate, pesticides, mining wastes) these should (hopefully) be monitored and dealt with by the water suppliers (Huss, 1994).

Very often water must undergo treatment disinfection prior to use. The following chemicals are used as disinfectants: chlorine, chloramine, ozone or UV irradiation. Chlorination is the cheapest form of treatment and monitoring of chlorine is relatively easy. According to WHO (1984) the concentration of chlorine in water should be in the range 0.2-0.5 mg/l. For sanitation purposes it may reach 200 mg/l, but in order to avoid corrosion lower concentrations are advised (50-100 mg/l).

6.3.2 Cleaning and disinfection

Cleaning and disinfection are the most frequent operations in modern food processing. Carelessness may cause considerable economic loss, and loss of reputation on the market.

The hygienic standards respected in processing plants depend on kinds of production. For example, in the cannery they will be more strict than in plants where fish is only gutted and stored in ice and its shelf life is rather short.

Regarding all other technological operations and processes, cleaning and disinfection procedures must follow detailed instructions and responsible personnel be assigned.

Various steps should be included in a complete cycle of cleaning and disinfection (Huss, 1994):

1. Remove food products, clear area from bins, containers, etc.

2. Dismantle equipment to expose surfaces to be cleaned. Remove small equipment, parts and fittings to be cleaned in a specified area. Cover sensitive installations to protect them against water, etc.

3. Clear the area, machines and equipment of food residues by flushing with water (cold or hot) and by using brushes, brooms, etc.

4. Apply the cleaning agent and use mechanical energy (e.g., pressure and brushes) as required.

5. Rinse thoroughly with water to completely remove the cleaning agent after the appropriate contact time (residues may completely inhibit the effect of disinfection).

6. Control of cleaning.

7. Sterilization by chemical disinfection or heat.

8. Rinse off the sterilant with water after the appropriate contact time. This final rinse is not needed for sterilants, e.g., H_2O_2 based formulations which decompose rapidly.

9. After final rinsing, equipment is reassembled and allowed to dry.

10. Control of cleaning and disinfection.

11. In some cases it will be good practice to re-disinfect (e.g., with hot water or low levels of chlorine) just before production recommences.

As mentioned above, only agents and disinfectants permitted by adequate regulations, can be used for cleaning and disinfection operations. During their use precautionary measures must be observed and this requires proper training of personnel.

6.4 Quality Aspects of Freshwater Fish Processing

6.4.1 Public health aspects

The term quality has many different implications, e.g., product excellence, value, nutrition, safety for consumer, etc. This section discusses quality requirements with respect to safety for the consumer and quality control principles.

In a free market economy the producers are responsible for food quality and they are controlled by the competent authorities according to approved procedures. Certain countries or groups of countries, e.g., European Union, formulate regulations specifying requirements concerning health quality, wholesomeness of raw materials and food/fish products and concerning permissible limits for chemical contaminants (heavy metals, PCBs, etc.) or biological infestants (parasites, microbes, etc.). Other regulations concern quality of water provided for food processing (see 6.3.1. "Water quality in processing and cleaning"). These regulations are of rather general character but there are others which concern health conditions for processing and placing of products on the market. Due to an almost complete lack of detailed standards for individual products, the regulations on labelling (see 5.3. "Requirements for the labelling of freshwater fish products") are of great importance, especially if the "fair trade" principle and consumer interest are to be taken into account. All these groups of obligatory regulations should ensure production of food which is safe for the consumer (Huss, 1994).

Additionally the monitoring of raw materials is a complementary part of activities carried out according to requirements contained in regulations. It provides the competent authorities, responsible for supervision of production, with information about potential hazard.

As mentioned earlier, producers are responsible for food quality. Besides the competent authorities such as the Ministry of Health, Ministry of Agriculture and Veterinary Services and consumer organizations or associations, producers also participate in creating new food laws. Such cooperation enables rules corresponding to industrial reality to be created which at the same time ensure consumer safety. Moreover, guides such as: Good Manufacturing Practice, prepared by producer associations, or Codes of Good Manufacturing Practice elaborated by FAO/WHO, are complementary tools widely used in assuring product quality (Codex Alimentarius, 1969). They lay down detailed technological procedures and recommendations for production. Provided they are respected by the producer the expected product quality is reached and consumer safety ensured.

Familiarization with principles contained in these guides and codes is important especially in the case of small food processing plants which unfortunately are often directed by people without adequate professional qualifications and training.

Rules and regulations of US FDA codes and standards of FAO/WHO, Council Directives of EEC (EU) set out an approach to the issue of health quality assurance. According to the above regulations, the main principle is that fish and fish products constitute a source of potential health hazard and danger for consumer safety. Many requirements, regulations, supervision, controls, inspections and governmental interventions stem from that principle.

Listed below are some basic regulations on requirements for fish and fish products from aquaculture, which are either compulsory or have been introduced in European Union countries. These documents concern also Third Countries which export fish and fish products to the EU market. Requirements in this context are covered by the following documents:

1. Council Directive (91/67/EEC) of 28 January 1991 concerning the health conditions of animals destined for marketing and originating from aquaculture

2. Council Directive (91/493/EEC) of 22 July 1991 laying down the health conditions for the production and the placing of fishery products on the market

3. Council Regulation (EEC No 3759/92) of 17 December 1992 on the common organization of the market in fishery and aquaculture products

This first directive states that animals must:

- be free of clinical signs of disease on the day of loading;

- not be directed for processing in order to liquidate such diseases as:

  - Infectious haematopoietic necrosis (IHN),
  - Viral haemorrhagic septicaemia (VHS),
  - Infectious pancreatic necrosis (IPN),
  - Bacterial kidney disease (BKD),
  - Spring viremia of carp (SVC),
  - Enteric red mouth disease (ERM)
  - Gyrodactylosis (Gyrodactylus salaris)
  - Myxobolosis (Myxosomiasis - whirling disease);

- not come from a farm which is closed due to diseases, and must not be in contact with fish from such a farm;

- be subject to the same requirements if directed for farming;

- be delivered, in the case of aquaculture fish, in the shortest possible time to the destination, and the change of water must only be done in specified places. Such places must be known to European Union countries;

- the Commission checks if regions are free of diseases, approves them and can, within reason, also revoke approval of the decision; and finally makes a list of approved fish farms;

- permission may be granted for placing on the market fish from aquaculture and from regions not approved but under special conditions. Such instances require documentation confirming the wholesomeness of fish from this region, and this must be issued by official inspectors, for example, by the competent veterinary authorities.

The region can be approved as free of diseases if it meets at least two requirements:

- the diseases listed above did not occur for at least four years,

- all fish farms located in this region are under continuous veterinary supervision and are inspected at least twice a year.

Veterinary inspection should cover the visual assessment of aquaculture fish wholesomeness, taking of fish samples and immediately sending them to the competent laboratory. Each farm must record all necessary data pertaining to the wholesomeness of fish including the official certificate of laboratory analysis. It is pointed out that only certificates issued by official control authorities are valid and placing of fish in the fish farm or for sale has to be formally documented.

The above rules concern all the fish being sold domestically and not only the fish directed for European markets.

Fish processing plants which, apart from farming carry out processing must obtain the approval of veterinary authorities to export their products. Acquiring a registration number is a formal approval to export fish. This registration number enables identification of the fish product, and this number must be shown on the label of each package and on the relevant documents.

Aquaculture fish and fish products exported to the EU must fulfil the conditions specified in Council Directive 91/493/EEC. The level of requirements in this Directive indicates that many fish processing plants will face great difficulty in obtaining an export licence. Thus each establishment should draw up its own production programme covering for example:

- kind of production (for example fresh fish, frozen fish, canned products, etc.),
- volume of production (daily, annual),
- production rooms and store rooms,
- technical equipment,
- sanitary facilities for staff,
- written schedule of quality assurance system and adherence to it

The competent veterinary authorities evaluate the production capacity and possibilities of fulfilling the production programme, taking into account the technical abilities and insurance of adequate sanitary conditions.

6.4.2 Quality control

Control is traditionally limited to control of the final product. Practice has proved that this is not sufficient and that quality control should be carried out during all stages of production, starting from a contract on supply of raw material, through all the phases of processing, to storage and distribution of final products. Such an approach is not quality control but constitutes quality assurance, which covers the entire production chain. Below, principles relating to quality control are presented with regard to the main individual operations and procedures in fish processing (Huss, 1988).

1. *Drawing up a contract for raw material supply*

The contract for supply of raw material should cover all specific requirements, for example: size of fish, closed seasons, level of chemical contaminants in fish and in the water from which the fish comes, and chemical measurements should be made by an institution which deals with monitoring of environment. Sometimes, especially in the case of export, the buyer/customer may have additional demands, e.g., an indication of the level of chemical contaminants other than standard ones. The buyer should ensure that he will receive the health certificate for his raw material and that the certificate was issued by the official control authorities. He should also obtain confirmation that the fish was stored properly prior to sale (for example, that fish was iced with a proper amount of ice and that the quality of the ice was satisfactory; that it was stored in cool store rooms and that it was transported by appropriate means). The contract may specify that some of these demands be passed to the receiver.

2. *Receiving and storage of raw material*

This control step determines the quality of the final product and should be carried out extremely carefully. In general it consists of three elements:

- temperature control of fish during transportation (temperature record)
- temperature control of fish and control of icing
- quality control of purchased fish

The temperature of the fish hold in the transport system is usually registered automatically or periodically by a driver. This temperature record is part of the documentation on fish shipment. Measurements of real temperature of fish tissue and control of icing are made on random samples. Apart from these elements the cleanliness of the means of transport and the containers, and the labelling, are checked. The number of samples/packages with fish to be further assessed depends on lot size, and it should be specified clearly in compulsory procedures or codes of good manufacturing practice, perhaps in the standards or contract specifications. The temperature of purchased fish should be close to ice melting temperature and not higher than 4°C. The samples of fish taken for temperature measurement are at the same time the samples examined for quality control of

raw material. Usually in the case of medium size batches eight packages are taken and in each package three temperature checks are made.

Detailed quality assessment is made according to requirements laid down in procedures, codes or standards if the latter exist. Such an assessment is carried out on an average sample from a set of randomly selected packages.

The sensory analysis of raw material is a main part of control, and it allows full characteristics of the fish investigated to be obtained. This analysis includes appearance of skin, eyes, gills and fish as a whole, colour of fish tissue; damage to fish, springiness of meat tissue, flavour of individual organs; flavour, taste and texture of meat tissue after cooking. Occurrence of inadmissible features like for example sour smell of gills, strange/unfamiliar smell of meat or fish as a whole causes that raw material is disqualified and excluded as a material intended for processing. In the case of live fish their appearance and movement in the water in a container are assessed.

The kind and the degree of infestation with parasites determines further procedure. If the presence of parasites which are harmful for humans is detected, fish cannot be sold as fresh. As mentioned above, this matter should be considered by the receiver when the contract is prepared. The final result of quality control of raw material is decisive with respect to further procedure during fish processing. Generally when fish is qualified as conforming with requirements and cooled properly it is placed in cold stores or transported direct to the processing line. Ice is added to fish cooled insufficiently and this is placed in cold store. The temperature inside the cold store should be close to 0°C and should be continuously recorded. If temperature cannot be registered automatically, measurements should be taken not less frequently than every two hours.

3. *Quality control during the production process*

The quality control programme during the production process depends on the profile of production carried out in the processing plant. Each processing plant must draw up a flow chart of the entire process starting from the raw material through every individual operation and process to the final product and with all quality control points indicated. Criteria for selection of control points depend on potential hazards which, in the case of lack of proper handling, can cause a risk for both the food and the consumer. For example, control of temperature during individual operations, their duration, concentration of food additives, etc., are typical and critical parameters measured at control points.

Technological supervision is responsible for use of adequate processing parameters. Quality control personnel are responsible for monitoring these parameters and in the case of deviation they should undertake proper corrective action.

The final step in production control is the quality control of the final product according to technical requirements and specifications included in the contract or standards if the latter are compulsory. Such assessment is carried out according to approved procedures with special regard to health quality requirements pertaining in a given country. This type of control will disappear in the future because an introduction of quality assurance

systems, as a continuous control throughout the entire processing procedure, will eliminate this traditional form of control (Bonell, 1994; Jakobsen and Lillie, 1992; Huss, 1994).

Quality control personnel are also responsible for supervision of assurance of cleanliness and disinfection of production lines and processing rooms. Maintenance of cleanliness and disinfection should be carried out in accordance with a programme approved by the local veterinary service. The quality control staff assures adherence to this programme which especially concerns:

- types of detergents/disinfectants and concentrations used;
- compliance with procedures of cleaning/washing and disinfection;
- arrangement of periodic microbiological measurements on the surface of equipment and processing machines;
- control of personal hygiene of staff including working clothes and sanitary fittings in the plant.

In summary, the quality control staff is responsible for carrying out this programme and for the sanitary-hygienic conditions of the processing plant and for maintaining the documentation relating to these activities.

4. *Storage and distribution of freshwater fish products*

The fish products directed for the storage or for the purchaser are random checked by the internal quality control staff. This control, *inter alia*, concerns:

- proper packaging materials and labelling (according to official requirements);
- duration and temperature of storage;
- proper conditions of storage, for example adequate ice, temperature etc;
- choice of means of transportation and hygienic conditions (cleanliness, temperature record, etc.);
- proper loading (e.g., arrangement of load in vehicles).

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